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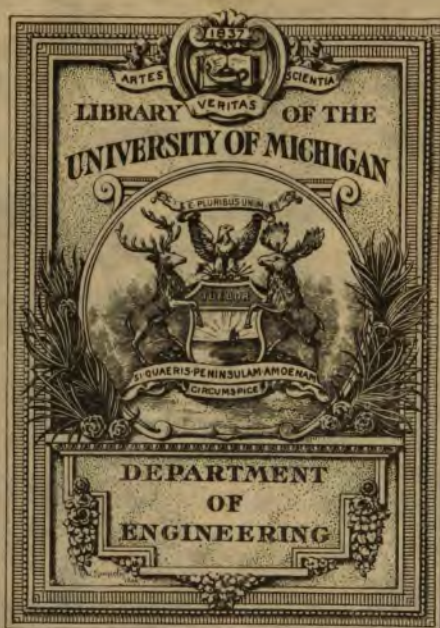
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MACHINE SHOP PRACTICE

A STUDY OF CONDITIONS FOR USES IN
TRADE, INDUSTRIAL AND TECHNICAL SCHOOLS
AND
MODERN MACHINE SHOPS AND MANU-
FACTURING PLANTS

BY

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PREFACE

THE trifling things of life make up the sum total of existence, and faithfulness to these trifles is of much more value than talent, and genius is only another name for hard work and constant loyalty to these little things. Therefore the purpose of this volume is *not* to deal with the big things of Machine Shop Practice, nor is it designed as a comprehensive treatise on the subject, but primarily to deal with those things which seemed too small to notice. by those who have already written so ably on the subject, and to connect them together by classifying them and bringing out their really great importance in the general order of things pertaining to the Craft, and by them to prove the good old law.

The author believes that it is so arranged as to be valuable as a text-book in the trade, industrial and technical schools, and that the apprentice and journeyman machinist will be able to use it with profit in his daily work. The fundamentals only are covered, but these are treated from the standpoint that each will fit into the other and the whole form a groundwork upon which substantially to build.

The whole is considered from the How and the Why, the Theory and the Practice. Much thought has been given to the method of presentation, so that the old things may appear in a new light and the hard things be presented so that they will appeal to the reader's common sense.

The subject-matter may not appear in the logical sequence that is regarded by some as the *only way*, but each subject

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is treated completely in itself to make a complete rung of the ladder by which to climb, a logical whole.

To the man who is desirous of climbing it is essential that he build his own ladder, that he may know the strength of each rung. The building process may vary, notwithstanding some old "saws" to the contrary; the top rung or the middle one, may be put in first, it matters not, so long as one never loses sight of the relation it must bear to those that are to follow to make a whole, and that the strength of the work as a whole is determined by its weakest rung. Seldom is the book that is most logical the best one from which to teach.

Because our forefathers, from whom perhaps we may have inherited our taste for like things, started to build their ladder by scraping grease, holding the torch, or oiling the ratchet drill for the man above, it does not necessarily follow that it is the only way to *arrive*. Every man will have that to do some time in life. No matter how high in position or responsibility and trust, there will always be some grease to scrape, some torch to hold, or some drill to oil for the man higher up, and to those who have already learned that lesson, the author would say, "Don't bother to read this text—you have already arrived, provided you can scrape grease, hold torches and do the oiling with a smile."

The text is primarily based on a series of mimeograph sheets which have been tried out for a period of twelve years, and their efficiency measured by the efficiency of the men who have built their ladder in this way. The author has aimed to do away with all useless energy and so arranged the text that the greatest efficiency would be possible with the least possible waste of time to the student or apprentice.

In conclusion, the author wishes to say that it is with a sincere desire only to help the other fellow and in an humble way, as best he knows how, he is presenting this

PREFACE

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volume, also to express his obligation to the many machine builders who have helped him develop the work by criticism and suggestions, and especially to Mr. H. D. Burghardt of Pratt Institute and Professor R. W. Burnham of Erasmus Hall High School, who have contributed much to the details of the work.

W. J. KAUP.

BROOKLYN, N. Y., February, 1911.

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MACHINE SHOP PRACTICE

CHAPTER I

VICE WORK

INTRODUCTION

Laying out work. The shape. Value and correct use of facet as guide. Economic angle for chisel. Why. Materials used and different cutting action. Value of straight face on chisel. Resistance of metal to hammer blow or force. How it varies. Construction of vise. How to hold work. Weight of hammer in relation to work. Length of handle. Cape chisel practice. Various types of chisels.

It is true that in modern practice much of the work that was formerly done on the *vise* by hammer, chisel, and file, is now machined, yet it is nevertheless true that a knowledge of vise work and the hand tools is necessary to modern high-grade mechanics, and their knowledge very often proves the means whereby they make good in their respective positions.

A brief description of the names and uses of the commoner kind of chisels is here given, with the various files used for finishing rough surfaces, but it is well to remember that a knowledge of the tools themselves is of very little value unless they are considered as means to an end.

In the exercises of this course, five distinctive steps are recorded:

First, Tools and their construction.

Second, To train the *eye*.

Third, To train the sense of *touch*, which is more accurate than the eye.

Fourth, The method of checking the inaccuracy of both and how to prove accuracy.

Fifth, The method of locating inaccuracy.

Tools Necessary for Laying out Work on Vise. Small square; scribe for marking lines; dividers (spring); chalk, or bluestone solution; prick punch; 1 lb. hammer (ball peen); 6" scale; calipers (outside); small hammer for outline work.

See that the prick punch is sharp.

In marking outline, use very light blow to insure absolute removal of all marks after finishing.

NOTE: Read drawing or blue print very carefully before starting to lay out work, and know what you are going to do before starting. A few minutes' time spent in careful study before starting very often avoids spoiled work.

See that the vise jaws come together parallel.

Do not use too much force in screwing up vise; if the work fails to hold, look for the reason elsewhere; you will invariably find that the work itself is not parallel, as in the case of all castings having a certain amount of draft, as this is necessary in the pattern to enable the molder to draw it from the sand without disturbing the sand mold.

Small pieces of cardboard will prove efficient when held between the work and the vise jaws.

Get into the habit of cleanliness. Keep the work bench and vise clean. **Cleanliness is the first essential of a good mechanic.**

CAST-IRON CHIPPING

Bevel Block. Flat Chisel. 1. Read drawing carefully preparatory to laying out work.

2. Chalk surface of block, where lines are to be drawn. By rubbing finger over the chalked part, a better surface is obtained.

Lay out one edge of block first, for practice chipping.

3. See that chisel is sharp and ground to proper angles, also that hammer handle is tight in eye. (Give proper angle in notes.)

4. Chip toward the dead or stationary jaw of vise always. Give reasons.

5. Start with light chip, and light blow; watch only the cutting edge of chisel—*not top*. Hold hammer at extreme end of handle. Note reasons.

6. Do not cut to line; leave from $\frac{1}{16}$ to $\frac{1}{32}$ for finishing cut. Rough all surfaces before finishing. Regrind chisel before taking finishing cut.

7. Keep in mind that the resistance of the metal to the hammer blow decreases as you near the end. Note how to overcome breaking off at the ends.

8. Cutting speed and cutting feed can easily be determined on vise as machine. Note length of time required to chip one end with roughing cut; also with finishing cut, and compute the cutting speed and feed.

Angle Plate. Cape and Flat. 1. Read drawing carefully, and note amount of stock allowed for finish.

2. Surface being broader than flat chisel, use cape or key way chisel, and run two grooves, equally spaced deep enough to get under the skin or scale of casting. Note fully the reasons.

3. Chip one surface perfectly flat before starting the other side.

4. Chip second side, maintaining right angle.

5. Observe same rules for holding in vise as in previous exercise.

6. Note fully in your report reasons underlying each move, nature of the metal, scale, value of using the cape chisel on broad surfaces, etc.

No lubricant; give reason.

7. Figure time required to rough, time required to finish, and cutting feed.

HAMMER AND CHISEL

Chipping. In introducing our elementary steps in the machine shop, we presume on the knowledge that all are beginners and unacquainted with tools and their uses. To those who have had some little experience in different shops (while not in direct application of the several principles), it will also prove valuable to learn, not only the uses of the tools, but the reasons underlying their construction in various shapes.

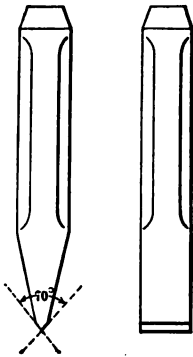


FIG. 1.

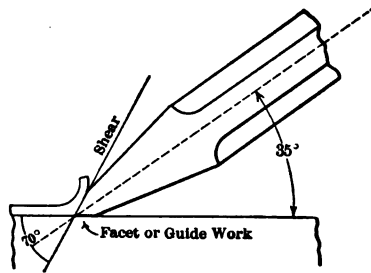


FIG. 2.

Our first lesson is chipping, and we have to do with chisels. To know the proper angle of the facets or edges is important, and what relation their facets have to the proper holding and use of the chisel is more so. Our first chisel is called a flat, and is made of octagonal tool steel, forged to a flat of $\frac{1}{8}$ " on one end, said flat to be parallel with one of the sides of the octagonal steel, which will enable you to hold it better on level surfaces.

The edges or facets are ground about $\frac{3}{32}$ " wide on each side of the center line of chisel at an angle of 35° , making the complete angle of 70° as in Fig. 1. I say 70° because by experimenting with chisels of different angles, I find

70° to be a safe angle for all around work, more efficient as to quality and quantity of work, and will do more work with fewer number of redressings. In adopting that angle for our use, I have also discovered that the angle at which the chisel is held by the workman is about 35°, which means that he is using the edges of the chisel as a guide and rest, as in Fig. 2. This is right, and what it is intended for. You will readily see that there must be a determining angle, by that I mean an angle that will cut heavy chips as well as light, and an angle that will not turn over or break. Run to extremes to get the

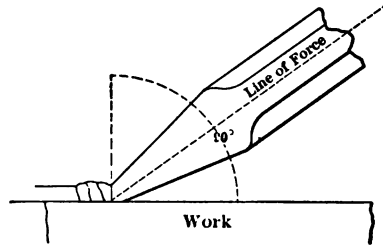


FIG. 3.

law, and take the angle of a wood chisel, which is good for non-resisting material, such as wood, would not do for the metals, owing to its being too acute and the edge would turn over at once.

Again, the angle, we will say, is 90°, and the force applied by a hammer blow would exert as much pressure down as it would in line of the cut, and would not do good work because it would not cut, but crowd the metal off.

We now know a very important point to begin with, namely, the angle of the chisel, and why it is so made. It is very important to know how to keep that angle during repeated grindings.

Note the uneven surface of the grindstone; if chisel were held on as in Fig. 4, we would grind the same uneven

face on the chisel, which is not desirable, and would defeat good work. Fig. 5 shows the chisel held at an angle, and moved in an arc over the surface of the stone, thereby insuring the whole surface of chisel passing the high point on stone during its travel. Another point—the facets should always be ground straight and not rounding, as in Fig. 6. Why? Because you would lose the all-important guide.

Thoroughly knowing the tool we are to work with, we will take up the work. It is essential that you acquire, as speedily as possible, a knowledge of drawing, at least to the degree of being able to read drawings correctly.

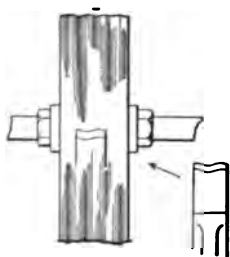


FIG. 4.

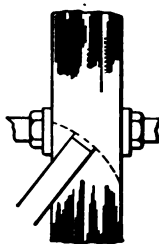


FIG. 5.

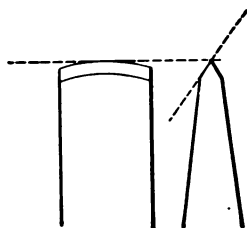


FIG. 6.

First study your drawing preparatory to laying out the work, and be sure that you know what you are going to do before you make a beginning. That is the all-important thing, and don't be afraid to ask questions. In that way we know whether a man is progressing. The drawing shows a completed exercise. Lay block on drawing and you will note that it is the size of outside line of drawing.

The $\frac{3}{8}$ " line means that the dividers are set to $\frac{3}{8}$ " and a line drawn along the edges all around the block. It also shows $\frac{3}{8}$ " deep, so the line may be drawn with dividers all around the lower edges of block. Note, only one setting of dividers. Now as to holding it in the vise, there is a right and a wrong way. What part of the vise will give the greatest

resistance to the constant hammer blows? The solid or immovable part *A*, Fig. 7, hence we work against that. Hold the work at such an angle that both working lines come in line of vision. As to the weight of hammers, they vary according to the work and shop.

The weight of hammers used in earlier days (and perhaps for some work are used to-day) was $1\frac{1}{2}$ lbs., but they were used for very heavy work, with no fine chipping. For all-around chipping, a 1-lb. hammer will do more effective and better work than the heavier hammer.

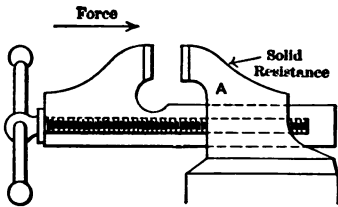


FIG. 7.

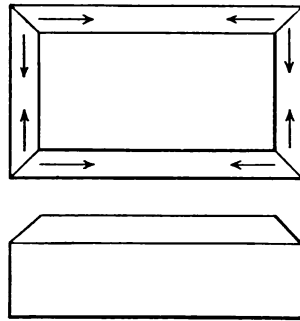


FIG. 8.

The length of handle should be 12 to 14 or 15". Hand should grasp extreme end of handle and hammer should be thrown back vertically over shoulder with wrist and elbow movement only. Do not hold chisel too tightly. By doing so you tighten the cords in wrist and every vibration caused by blow of hammer will tend to make the wrist lame.

We now come to another important point. In starting your cut you have the resistance of all the metal in the block. As you approach the end of the block the resistance is gradually decreasing. The force applied by hammer must decrease also, or the end will break off, and possibly below the line of work, which would spoil it. To avoid

that danger, we first chip off the corner, as in Fig. 8. The finer the cut, the less force applied, or lighter the blow; hence the resistance must always be greater than force applied.

Our second piece of chipping has to deal with a broader surface or one wider than the flat chisel. To facilitate work and save time we introduce what is called the cape chisel.

It is made of same style and grade of steel, but is narrow.

This chisel is commonly used for key seating, using different width cape chisels for different width keys.

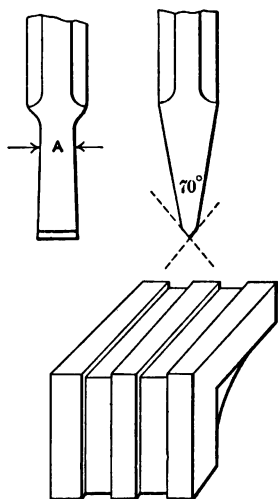


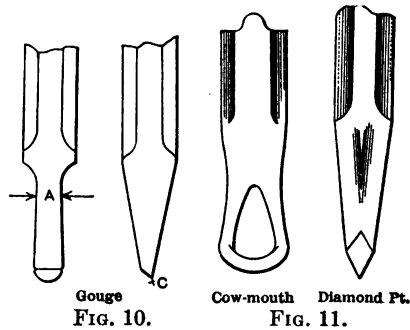
FIG. 9.—The Cape Chisel.

You will notice the advantage of grooving the broad surface with the cape chisel, leaving the metal standing narrower than the width of flat chisel, also enabling you to use the grooves already cut as guides for sides of flat chisel. Bear in mind again that as you near the edges, the resistance decreases and the edges are liable to break out. Avoid that by working from both edges toward the center.

We have thus far dealt with cast iron only, which is porous and brittle, and non-fibrous. Wrought metal is homogeneous, that is, solid and massed together in fibers, is long and tough, and will not break off, but will curl the chip.

More force must be applied—that is, heavier blows must be struck to take the same size chip on wrought metal as on cast metal. In chipping wrought metal, lubricate the end of chisel by occasionally dipping into a piece of oil-soaked waste, placed conveniently on end of vise.

Fig. 10 is still another form of chisel, called gouge or round nose, used for chipping oil grooves in pulleys, bearings, etc. This chisel should be ground thinner at *A* than at cutting edge, to avoid the wedge principle, *B*, which would



raise a burr on sides of oil grooves. This is also true of cape chisels. A slight change in angle is made as at *C*, to make it possible to increase the depth of cut by raising the chisel. The larger sizes of these chisels are used for chipping circular work.

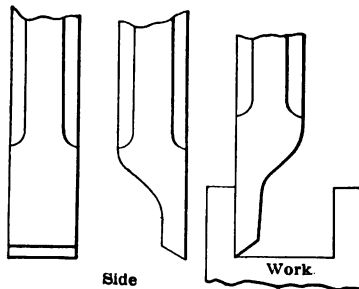


FIG. 12.

Fig. 11 is still another form of chisel, called, from its shape, diamond point. It is used by die makers and for corner chippings.

Fig. 12 is still another form of chisel which is more com-

mon among tool makers than machinists. It is used for squaring sides of dies and punches and chipping square holes of different depths.

A thorough knowledge of chisels and proper use of them will produce work of fine art variety.

QUESTIONS ON CHIPPING

What is the best angle for a cold chisel?

What are the objections to a sharper angle?

What are the objections to a more blunt angle?

On a grindstone with grooves, how can a cold chisel be sharpened flat?

About how wide should the facets of a cold chisel be?

What are the objections to a cold chisel sharpened to 70° but with a curved edge?

About what weight of hammer should be used in chipping?

Where should the handle be grasped?

What arm joints should mainly be used in moving the hammer?

Should the hammer head be thrown back over the shoulder at each stroke? Why?

Where and how should the chisel be grasped?

Toward which jaw of the vise should chipping always be directed? Why?

Should chipping be continued toward and up to the end of a block? Why?

If the work slips in the vise, how can it be avoided, otherwise than by tightening the vise? Three ways.

Should a cold chisel ever be lubricated? If so, when and how?

What chisels other than flat chisels are in common use?

For what kinds of work is each adapted?

How is the burring of the sides of a chisel-cut groove prevented?

CAST-IRON FILING

Angle Plate. S. C. Bastard File. 1. Select proper file, 12" bastard; sight along edge and find the greatest convexity. Chalk opposite side with X. Note reasons.

2. If right handed, file from right to left, and vice versa.

3. Balance the file by laying on work, and apply the pressure with left hand on extreme end of file.

4. File should cut only on forward stroke; relieve on return.

5. In notes give proper position at vise; importance of the convex sides; why the teeth are cut on angle; what is meant by increment cut; what happens if surface is oily.

In general, note fully what result it is desired to obtain.

6. With exception of the different kinds of files for the different exercises, this exercise sheet covers all cast-iron filings.

CHAPTER II

FILING

Shape and value of filing in economic production. The shearing cut. How chip resistance is minimized. Different kinds of files and their uses. Value of keeping clean. Penning. Draw Filing. Increment cut and its origin in file construction.

THERE are many kinds of files, and into their use very many factors enter, tending to make the results very difficult unless there is average intelligence used in operating them.

To attain this intelligence, we lay down certain principles to be followed by the student or operator, and much depends upon the aptitude with which these principles are grasped.

First, the selection of a file to do the required work. In selecting it, you must know the kind of metal and whether a narrow face or broad surface. Cast metals are harder to cut with files than wrought metals. Consequently we use new files and, for broad surfaces, where much metal is to be removed, coarse or rough-cut files. After these files are worn beyond the economic point for cast metals, they will be found still serviceable for wrought metals. Our first lesson is cast iron filing on broad surface. A roughing file is selected, having considerable convexity or curve on both sides, as in Fig. 13. First, however, see that the handle is properly affixed to file, for this is most important to the beginner. A well-made handle properly ferruled and smooth should be selected, and made to fit perfectly on the tine of the file, practically its entire length. This is done by taking a worn-out file of the same kind you

are about to use, heat the tine red hot and force on handle, sighting frequently by eye to get it straight and in line with file. I mentioned a worn file simply to avoid an error commonly made by beginners in fitting handles, and that is, drawing the temper in heel of new file while heating it. When it is necessary to use the new file, dip a piece of cotton waste into water and keep it wrapped around the heel of file to keep the temper from running.

The reason for selecting a file with convex sides as in Fig. 13 is this: The greater the number of teeth having bearing on work, the greater must be the pressure applied to make the file bite or cut. Teeth all having contact on work would require enormous pressure, whereas in Fig. 14, one-quarter that number, possibly, have contact, which means that the pressure would be reduced three-quarters. Files are made that way especially for that purpose, but sometimes in hardening they warp and all the convexity is on one side, while the other side will be hollow.

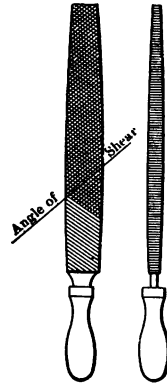


FIG. 13.

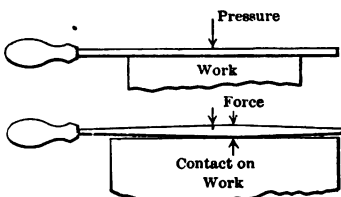


FIG. 14.

In beginning work, sight along the edge of file and always use the convex or outer curved side, as at *F* in Fig. 13.

Now we know three important things: First, that we use new files on cast metals.

Second, coarse files for removing much stock for broad surfaces.

Third, the value of the convexity of the file.

It is plain that the longer the bearing along the work sur-

face, the more easily can the file be balanced, and that balancing is the first step the beginner should acquire. Place the work in vise so that it will be slightly below the

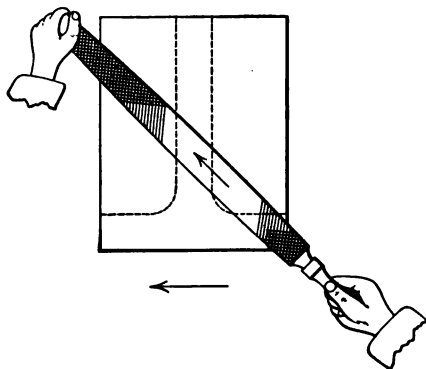


FIG. 15.

line of the elbow. This enables you to apply the pressure naturally and with less energy for the workman. Grasp the file with the end of the handle well back against the palm

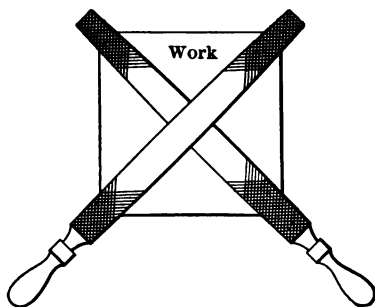


FIG. 16.

of hand, with thumb along the plane side of file, as in Fig. 15, the left hand palm resting on end of file, with elbow of left arm raised, for with that arm the pressure is applied.

Make the stroke forward as indicated by arrow *A*, with side tendency of arrow *B*.

In roughing down a surface it is permissible to cross and recross your file marks, as in Fig. 16. This is an economic way when much metal is to be removed, and is only permitted with the coarse files. The reason it is economy is that the file makes grooves along the surface, and changing the direction of stroke removes the tops of the ridges made by file in former cut. I prefer, however, to avoid the crossing, even in rough files, because it takes

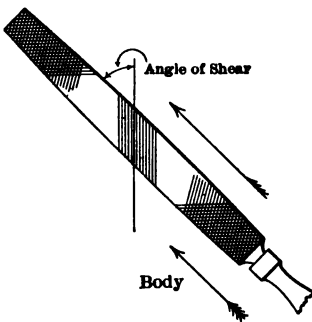


FIG. 17.

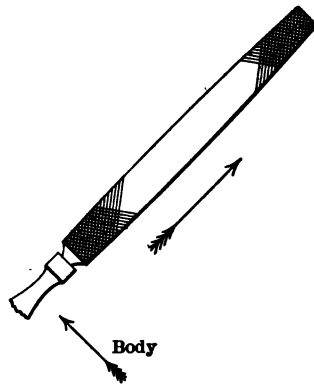


FIG. 18.

the beginner longer to learn straight, flat filing, and for this reason in filing from right to left, Fig. 17, the right arm is following in a line close to the body, and with short leverage.

In moving from left to right, as in Fig. 18, the arm leverage is extended and lessens the control of the file.

Stand naturally at vise. Make a full stroke forward, keeping right foot well behind the left and balance on left when making stroke. Avoid short, jerky strokes, and accustom yourself to the long, easy strokes, not applying much pressure at first, until you have accustomed yourself

to the proper return stroke. The pressure is always applied on forward stroke and relieved on the return stroke. The file is always returned resting on the work, not lifted each time, as file balance is thereby lost. The file must be firmly held, because the object is to make the stroke a straight and level one.

When the surface requires very little work to level, a second-cut or next finer file is used, but more care must be exercised in length of stroke, etc.

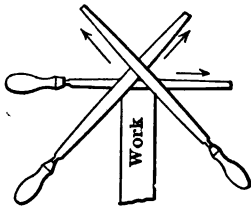


FIG. 19.

A worn file should be used in narrow work. Where much metal is to be removed, the edge filing is economy, as in Fig. 8. The contact area being small the bite of the file is free, when the surface is both narrow and thin, as in Fig. 19.

Fig. 20, the filing being straight across its width, would give the desired straightened work, and the error due to

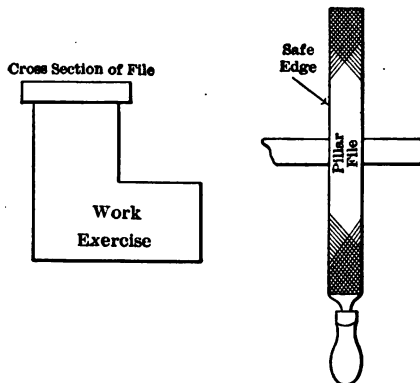


FIG. 20.

poor filing would be reduced to the narrow line of metal and would necessarily be the smallest error possible.

In corner filing, as in Exercise, Fig. 8, the safe edge second-cut file is used to protect one side of work while filing the other.

Always avoid a file that is very thin, as it bends readily under usage, and will give a rounding surface. Much time can be saved in filing by keeping the file free from its cuttings, as they tend to fill in the spaces between the teeth and pack themselves solid, thereby limiting the depth of bite of teeth. A sharp light blow on edge of file will remove most of the filings, but the file card, made for that purpose, is better. By chalking the face of the file, this can be obviated to a great extent, especially on cast metals. In wrought metals the filings become wedged into the grooves of files, and pin themselves above the teeth of the file and score and scratch the work. This is partly avoided by using a little oil on the face of the file. This is only permissible on fibrous materials, such as wrought metal, never on non-fibrous or cast metal.

In the third step, as indicated by Fig. 21, two pieces are necessary to check each step in the accuracy of measurement, and if accurately developed, should be interchangeable. It is primarily designed to teach accuracy by sense of touch, which is more sensitive to error than the sense of sight.

The economic can also be brought into it, and this, by the way, should be present in every step of the student or apprentice.

If these small, thin pieces were to be cast separately, a machining operation would be necessary to get a working face. The chances are also that the metal would be harder to work, owing to the quicker chill of small, thin pieces.

Fig. 22 shows clearly the way to avoid this by casting the shape in long pieces, and then sawing them to required thickness, which gives also the working faces without additional machining. Enough metal should be left all around, so that the workman can get down under the scale into good clean iron.

The beginner should have the step by which he climbs the ladder so arranged that his mind can be concentrated on one thing only at a time, and the work so carefully studied that he can build upon the preceding step with assurance.

In this third step there are but two settings of the calipers, as the piece has been developed with sizes that are interchangeable for the reasons already set forth.

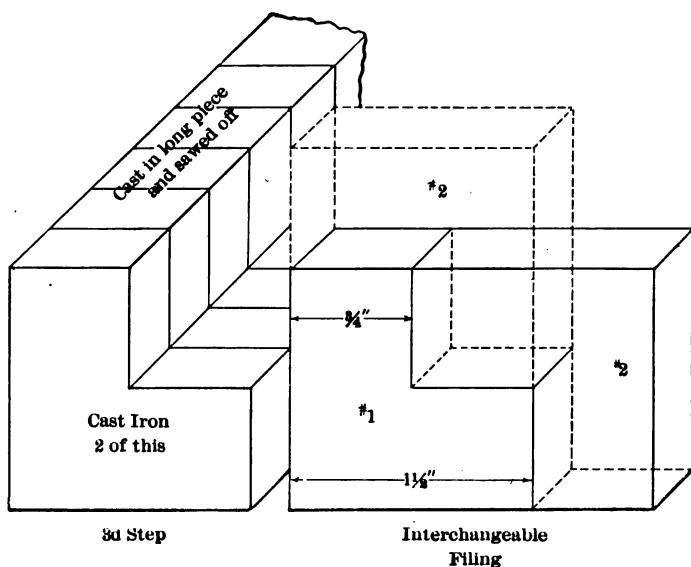


FIG. 22.

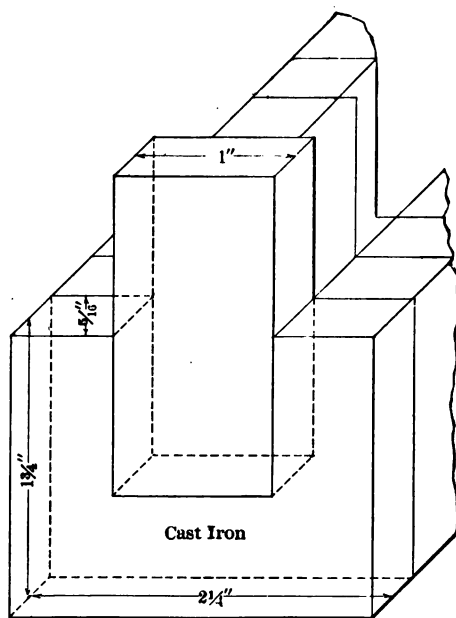
FIG. 21.

Skill is not really experience that comes from doing the same thing repeatedly. Skill is the combination of brains and hand, and can be attained in surprisingly short time if common sense is brought to bear upon the method of attacking each step of your problem.

Common sense and care = mind and hand.

Fig. 23, the fourth step, is the next link in the chain, and is designed to teach still greater accuracy, without

that attending skill. It furnishes a method of checking inaccuracy. Here again the caliper is used as accurately as the workman can on the plug gauge, which may not be more than a poor approximation. This gauge should be used now to calibrate the slot in which it is to slide, and by reversing it—turning it end for end—the error



Cast Iron
Plug Gauge
Filing
4th Step

FIG. 23.

is readily discovered and correction made on the gauge until finally the sides of the slit are parallel.

As the slot is enlarged the gauge should be used from time to time at right angles to the plane of the slot, and in this way the workman can check his parallelism. If it fits in top and bottom, and not in middle, it is clear that

his work is rounding and that he is not holding his file flat, but rocks it. If the steps have been carefully followed by the workman—that is, the outside squared and made

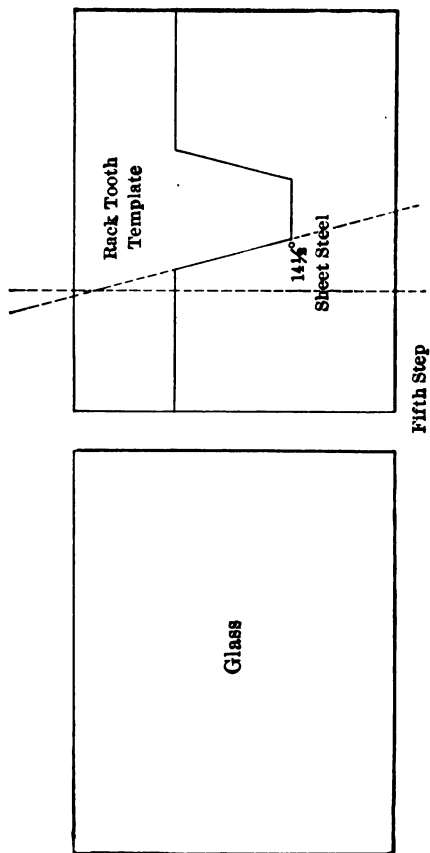


FIG. 24.

parallel—before starting on the slot, the caliper will prove an accurate means of sizing both legs, leaving a parallel slot and finally the plug gauge used only for sizing.

Fig. 24, the fifth and last step. In this last stage of the course the object is not so much to teach accurate filing

as to bring out a much more vital point in the simplest possible form, *where* the error in the work may actually be.

To remove metal in the wrong place spells failure, as the workman discovered who filed only the spots on the valve seat that did not touch, because he already had a good bearing on those spots that did touch.

The rack tooth template, to be of any value, must have like angles on the side of the tooth. By repeated reversing of the tooth in the space, using a glass plate to keep both pieces flat and in a plane, the error is easily located, but study of the error must be given to know whether it should be taken off the tooth or the side of the space.

Summary of the Steps. The first step is the introduction of the crude but necessary tools for either *machinist* or *tool maker*, the hammer and chisel, not because the manufacturing world to-day demands a product from these tools, but as the simplest and quickest method of impressing the workman with the value of the cutting angle and that the lighter the chip the lighter the blow, or that the force applied should approximately equal the resistance of the metal being cut.

Second Step. The introduction of other types of chisel for purely economic reasons, because it is the best way to remove metal on surfaces larger than the flat chisel and keep the whole surface in a more accurate plane, as the more regular the surface, the better the filing which follows can be accomplished.

In filing the surface, the balancing of the file is the most important thing to train the operator to face straight, and to use the eye to detect the error.

The second side of the angle plate calls for the same thought, but in addition to this it must bear a right-angle relation to the side already finished.

Third Step. The introduction of different files, and methods of using them, and the training of the sense of touch.

Fourth Step. Checking the inaccuracy of both eye and touch by positive method. Plug gauge.

Fifth Step. The making of a working tool, and in making it to teach method of locating trouble in its proper place.

The proficiency of any course depends entirely upon how closely the details have been followed, and those who are willing to give these steps a conscientious trial will satisfy themselves that such a course is not a theory but a *Fact*.

The workman should grind his own chisels under competent directions, and during the elementary work the lathe tools that have not been hardened should be given as filing exercises, so that proper angles, rakes and clearances can be studied before advancing to machine tools.

The tools also will furnish elementary use of the gas furnace in hardening and tempering, at a period when loss by failures is reduced to a minimum.

Never rub hand or finger over work if filing cast metals, as the surface of hand is coated with oil and it makes the surface hard to file.

Half-round files are used for circular work, as in Ex. 13, Fig. 25, and, as before stated, the coarse file is the primary file, followed by the fine.

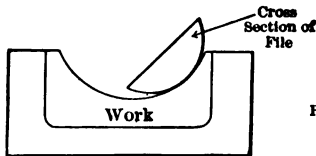


FIG. 25.

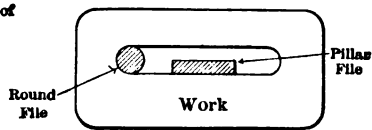


FIG. 26.

The pillar file, which is a very narrow file, and made only in the finer cuts, is used for slot and inside filings, square holes, etc.

The round is used for fillet work, as in Fig. 26. Another file used to some extent in the shop, is the mill saw, so named because of its special cut and adaptation to teeth

of mill saw. It is also called a float. The cutting is single cut, not a cross cut as in the ordinary files, as in Fig. 27. Its use is mostly for rotating work, such as lathe work, and should be avoided for many reasons. In the first place the lathe tool should finish the work and never rely on filing to fit. If finished with tool, it will be round; if filed, not so; but if it does become necessary, have the speed high and the stroke slow. This, of course, refers to the smaller diameters. Large diameters must necessarily run slower, and the stroke must necessarily run more slowly. The life of all files depends largely upon the metals filed. Tool steel approaches nearer to the hardness of the file teeth, consequently the life of the file will be shorter on it than on the softer metals. Avoid using good files on scale of castings or forgings, for it is very hard. Scale should be removed with the edge of file only, no matter whether old or new. The filed surfaces should be protected in vise jaws by either soft copper clamps or leather jaws.



FIG. 27.

The last lesson on filing treats on finishing work by draw filing, in which the motion of the file over the work

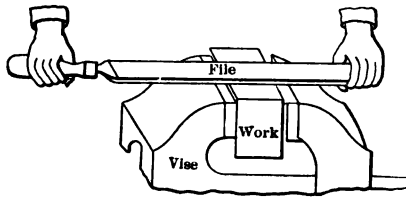


FIG. 28.

is at right angles to its length. The file is held as in Fig. 28. Remove the handle to better balance the file, as the curvature of the file can be brought in contact with the

high places on the work. It is plain that very accurate work will be the result if care is used in draw filing, and even the beginner can get a good result by this method. The file does not cut so deeply with given pressure, therefore does not remove much metal and removes it only where needed; hence the accuracy of the work. It also gives a finer finish, as the grain or lay produced by draw filing will be in direction of the stroke in plane of the work.

Oil is frequently used in draw filing to lay the grain, as mechanics call it, and give a finer finish. This is, of course, on fibrous material. After finishing with the file, chalk well and use file card. Do this several times and the file will be clear from oil, the chalk having absorbed it.

In the earlier days of files, they were made by hand and the teeth were as irregular as the skill of the mechanic who cut them. This made the teeth high in places as the cuts were deep and gave fewer contact points; which proved desirable, but the expense was necessarily great. Now machines are used whereby the cuts of the teeth are increased or decreased, giving the same effect as the earlier hand-cut files. These are called increment-cut files.

QUESTIONS ON FILING

Which is the easier metal to cut with a file? Cast iron or wrought iron?

Should a new or old file be used on cast iron? Why?

When should coarse files be used?

What are some of the most important things to be considered in selecting a file?

Of what use is the convexity of a file?

What advantage is gained by cross-cutting the teeth of a file?

In making the forward stroke in filing, should the side tendency be toward or away from one's body? Why?

Should the file be lifted from the work on the return stroke? Why?

On narrow work should an old or new file be used? Give reasons.

What can be done to keep cast-iron filings from clogging the file?

When greasy, how would you clean a file?

How should the scale on castings be removed, prior to filing the surface?

What are the objections to handling or fingering the surface which is being filed?

On the short side of the "corner fit" exercise, which way should it be filed?

On the long side?

What is meant by the term "draw-filing"?

What are the three common kinds of files? depending on their fineness?

What is meant by single- and by double-cut files? What are the advantages of each, and where used?

What is the advantage of a safe edge on a file?

Describe in detail the position of the workman at the vise, in relation to his work, height, etc.

CHAPTER III

SCRAPING

Its value in the field of machine construction. How straight surfaces are developed. Theory underlying it. Shapes of scrapers and their various uses in the trade.

Scrapers and their Proper Uses.—Our next step is to take the filed surfaces down to a more accurate finish, and to do this we employ hand tools called scrapers. This requires a delicacy of touch we have not quite attained in our use of files, but we first study the tools, as in our earlier lessons, to learn their natures before attempting their use.

Fig. 29 gives one style of scraper, double-ended type, made from $\frac{7}{16}$ octagonal steel, flattened on both ends and hardened as hard as file and water will make them. They should be ground straight along the edge *E* and not rounding, as shown in Fig. 30, for reasons which will be made clear to you afterward. Another style of scraper is shown in Fig. 31, used mostly for bearing work where you cannot get a free use of the straight-edge scraper. Still another style of scraper, Fig. 32, is made from a wornout, half round, smooth file, having all the teeth ground off on emery wheel. This is used principally for journal and box work for rotary shaft bearings.

The first question that naturally arises in the mind of the student or beginner is, "Why is it necessary to scrape a bearing when the work seemingly comes from the shaper or planer with a true surface?" Does it come from the machine true? All work that requires clamping or binding

in place to a machine, has certain pressure bearing upon it, which tends to distort its shape, and no matter how delicately clamped, it will be affected in a degree. No matter how solidly the work may be bedded on the platen of the machine, nor how well sustained the pressure may be in the direction of its compression by the clamps, it will spring, although it may be almost imperceptible. Another reason is that in the very nature of castings, no matter what the metal is, after the scale is removed it changes its shape.

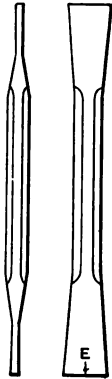


FIG. 29.



FIG. 30.



FIG. 31.



FIG. 32.

To scrape a pair of surface plates accurately a third plate must be used, as it is possible to scrape two surfaces together and still have the surfaces out of true, as in Fig. 33.

The first essential is to try the plates with straight edges to see if there is any wind or twist. This is done by placing the straight edges on both edges of plate and sighting over them. The straight edges being considerably longer than the plates, the error will be so multiplied as to be easily determined by sight. If there is much twist, file the high corners, as it is the most economical. Dismiss the idea that surfaces are scraped only to give a better

appearance to the work. We will now take 3 plates and mark them *A*, *B*, and *C*. Try *A* and *B* together, as in Fig. 34. Then *B* and *C*, after which any error will be readily discovered by trying *A* and *C* together. *A* and *B* may be scraped together, as in Fig. 35, with curved surfaces, *C* being scraped to suit the curve of *B*, when *A* and *C* would show as in Fig. 36. The reason why three plates are necessary is that one acts as a gauge to the other two.

The large surface plate which is found in all modern machine shops may be used as the third plate, but care should be exercised in using it. For instance, if the small



FIG. 33.



FIG. 34.

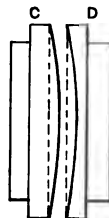


FIG. 35.

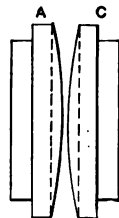


FIG. 36.

plates are rubbed on it in one place only, that place will wear and the surface become untrue, therefore in using it rub the work along the outer parts and corners as well as center. After rubbing the plates together, using a very light coating of red lead, Prussian blue, or lampblack, the high spots will show, if rubbed long enough. They will appear bright when rubbed hardest. These only should be scraped. The wide, flat scraper is used almost flat on the work, to avoid grooving the work, and that is why they should never be ground rounding as in Fig. 30, page 27. A rounding edge makes deep grooves, and as our object in scraping is to reduce the hill to the level of the valleys, we want to avoid making valleys with a rounding scraper. In finishing our surfaces, we first scrape in one direction,

then in another between the parts already scraped, which gives it the appearance in Fig. 37.

There are other places where scraping is used to a great extent, for instance, ways of a lathe, or the ram of a shaper. In these cases the parts themselves are used together one bearing being worked into the other.

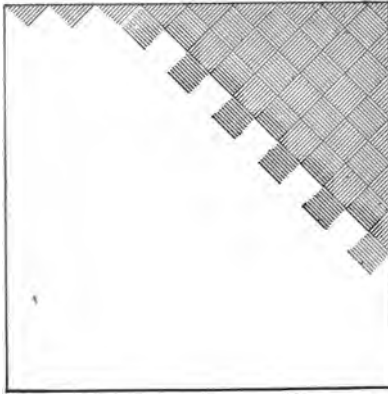


FIG. 37.

QUESTIONS ON SCRAPING

What is the value of scraping?

How should scrapers be ground?

What is the result if they are not properly ground?

How are the bearing points determined?

What materials are commonly used to show bearings?

What is the disadvantage of using red lead or Prussian blue too thickly?

Why is it necessary to use three plates?

What is the advantage of changing direction of scraping stroke in scraping a surface?

What is the advantage of a master plate?

CHAPTER IV

HAND TOOLS—PRACTICE

SPEED LATHES

The field for hand tool work, what it teaches. Conditions to be studied. Shapes and different uses of hand tools. The rest, its proper relation to the work.

Hand Tool Work. The importance of the speed lathe cannot be too greatly emphasized, not because the product from hand tools is in demand, for, on the contrary, the machine has become obsolete from that standpoint, but because of the rapidity with which the principles of proper cutting angles of tools, the different rakes, clearances, etc., can be learned. The beginner has the opportunity of comparing values, that is, by holding the tool at a certain angle a certain definite result is secured, and in starting another cut at a different tool angle a different result is obtained, by which the comparison can be made between the first and second conditions; it also fixes in his mind the proper elevation of the cutting edge of the tool for different metals. Here also, as in no other machine in the shop, can the student learn the disadvantage of end thrust and loose spindle bearings, because the impression prevails that in running at a high rate of speed a great amount of play is necessary to prevent heating of the journals.

If the journals are properly fitted to start with and the necessary care exercised in oiling, end play is not necessary.

The stop *a* should be set close to the work, and at such a height that the cutting edge of the tool can be brought on the center of the work to be turned; the fingers of the

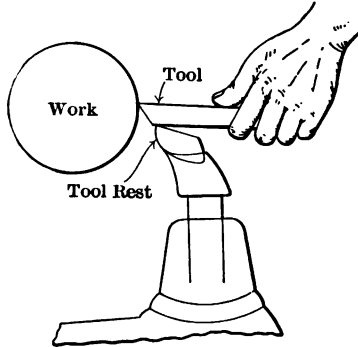
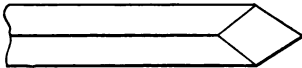


FIG. 38.

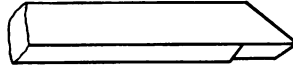
hand should grasp the rest on the bottom side and the thumb hold the tool down on top as in Fig. 38.

A small universal chuck is a requisite of the machine, and should be used without strain; the work should be



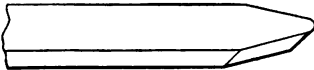
Turning and Finishing Tool.

FIG. 39.



Cutting-off Corner Tool.

FIG. 40.



Turning Tool.

FIG. 41.

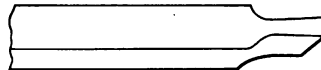
Cutting-off Tool,
Right and Left.

FIG. 42.

centered for the purpose of using the tail center as an end support. Herein lies an element of danger: the work, traveling at a high rate of speed, generates friction on the center, and quickly dries the lubrication, hence a thin oil

is not good; soap or tallow will prove more efficient, because, being heavy, it requires a higher degree of heat to melt, hence will last longer.

The handles should fit well up on the tool, and to insure this, the tang of the tool should be burned into the handle, the same as a file.

Figs. 39, 40, 41, 42 are different types of tools for use in speed or hand tool lathe. Diamond point, for turning, 39. Side tool, for facing, 40. Round nose, for brass turning, 41. Cut-off tool, 42.

QUESTIONS ON HAND TOOLS

Describe the different kinds of hand tools and their particular uses.

Why can proper cutting angles and clearances be best learned by hand tools?

What is one of the most important requirements about the machine upon which you do hand-tool work?

How should tool be supported and held?

Why is the consideration of leverage important?

CHAPTER V

MATERIALS OF CONSTRUCTION

Different kinds used and why. Cast iron and its application to modern construction. Bronze and its function. Crucible steel and its importance in the general build up. Theory of design.

It is essential that the mechanic who operates a machine as well as the student who is learning should be thoroughly familiar with, not only the different kinds of material used in the machine construction, but the *why* also, because with this knowledge he will be better able to get the machine efficiency. The efficient machine designer spends his best effort on the breaking-down point of the machine, that it be so located that it can be replaced at least cost and time.

All machinery that is subjected to high speeds is arranged to have the preponderance of wear take place in one particular part, as, for illustration, the bearings of the machine, which necessitates a softer metal than the shaft or spindle that runs in it.

For rotating machinery *two like metals are seldom used*. Not because they will not wear well, but chiefly because the wear would be distributed on shaft or spindle as well as bearing.

Cast iron and cast iron *can* be efficiently designed to run together, if the area of the wearing surfaces is large enough to reduce the frictional wear to a minimum.

The size of the shaft and the whole general design of the machine would have to be built on a very large scale.

There are machines on the market to-day with cast iron

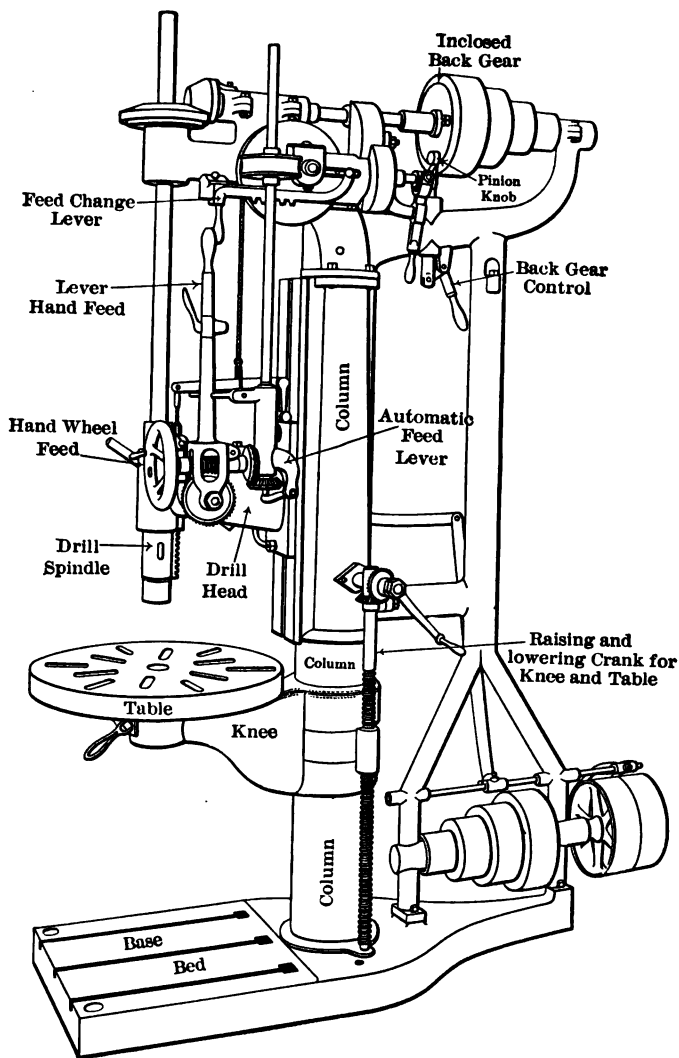


FIG. 43.—W. F. & J. Barnes Drill Press.

Bed (C. I.)	Column	Elevation screw	Knee	Table	Work
		Ways	Sliding	head	Feed mechanism
		Main spindle for driving			Drill spindle
		Transmission counter shaft (C. I.)			

Build up of machine, showing relation of parts to each other.

spindles of .8 to 12" diameters that will be satisfactory just as long as the first piece of dirt is kept from getting into the bearings. For spindle use, crucible machine steel lends itself economically to the design, as smaller diameters are available, due to its greater strength over cast iron.

These are usually designed to run in boxes or bearings of some softer material, such as brass or bronze or cast iron.

The economic law entering here is that the boxes can be replaced at less cost than could the spindle of the machine, hence the less wear there is on the spindle the longer the life, as the softer material takes the wear. This box or bearing is fitted into the casting which forms the main part of the machine, hence the three materials of construction are:

Cast iron for the main part of the machine.

Brass or bronze bearings which fit into this, and the

Crucible machine steel spindle.

The introduction of the bearings into the main castings is worth studying. *Why* is not the spindle made to fit without this extra piece of machine design? Take the head stock of a lathe, for example; if the spindle was fitted into the cast-iron head stock, after a short period the wear would be found to be in the softer metal or head stock, which would mean reboring and bushing it, a costly and tedious operation, which is avoided by the introduction of bearing boxes. With the same logic, the center, which is now designed to fit into the main spindle, might as well be turned as part of the main spindle, and although this is not the reason for inserting centers, its logic is just as reasonable.

Here again we can renew broken centers without the outlay of much time and money.

We do know that the main spindle is designed to carry a tool-steel center, a harder material than the spindle itself, because the centers must withstand all of the crushing

force of the whole load. They are also fitted to a taper. *Why?* Because they are more readily fitted into place, and more important than all else is that through this principle of taper fitting the accuracy and alignment is always maintained, for as the centers wear from constant taking out and putting back, the center will go in farther, but the centralization is not affected.

Cold-rolled steel shafting would in no sense be classed with the materials of construction; its efficiency lies in the field for which it was specially designed, that of use without disturbing its outside shell, for line shafting and power distribution.

When turned down, its efficiency is lost, and, due to the unequal strain of cold rolling, will not remain straight.

The materials of construction are so selected that the machine will have the maximum life with the minimum cost of up-keep.

CHAPTER VI

DRILL PRESSES—PRACTICE

DRILLS AND COUNTERBORES

Different kinds of drill presses. How classified. Drills and their proper angles and how determined. Counterbores and their functions. Methods of holding tapers. The value of care in handling. Cleanliness as an essential. How the crushing effect is reduced. Different forms of drill construction. Speeds and feeds. Sectional boring bars for long holes.

Too little attention is given to the importance of these tools, and usually the beginner in the shop is found running them.

The drill press in many of the shops of to-day is the only boring mill to be found in the plant, and all kinds of work are possible on this type of machine.

The usual designation of these machines is as follows:

The Sensitive Drill. The small press to be found for very small work is spring-controlled in its feed, which is by hand leverage.

The Common Type of Floor Drill. Designated by size of its table, such as 16", 18", 20", 22", and 24", round table, is a column construction and has power feed as well as hand feed.

There are three types of radial drill, and by radial we mean an extension arm which carries the drill head, the center of the drill spindle being always on a line intersecting the main column on which the arm rotates.

The Plain Radial. In which the arm is solid and the drill head always at right angles to the arm, or in plane with the column. No angular work can be done on the plain radial.

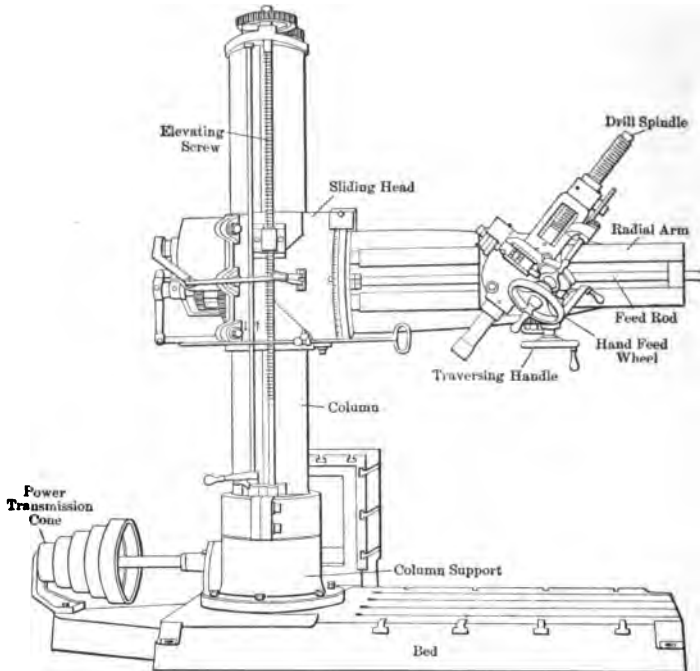


FIG. 44.—Radial Drill.

Parts and their relation to each other.

Bed (C. I.)	Column sup- port (Cast iron)	Column (C. I.)	Elevating screw				
			Radial arm (Cast iron)	Saddle (C. I.)	Drill head (Cast iron)	Spindles (Cru. steel)	Drill T.S.
			Transmission cone, (C. I.)		Field mechanism		

The Semi-universal. In which the drill head can swing at different angles, the arm remaining rigid. Certain angles can be drilled on this type.

The Full Universal. In which the arm, and also the drill head, can be rotated at different angles. This enables you to drill at any angle.

By far the most important boring tool in any shop is the drill, and experience has proven that with no other type of boring tool have there been so many disappointing results as with drills. It must be patent to every mechanic that the cutting edges of the drill should have a uniform angle with the longitudinal axis of the drill, and they should

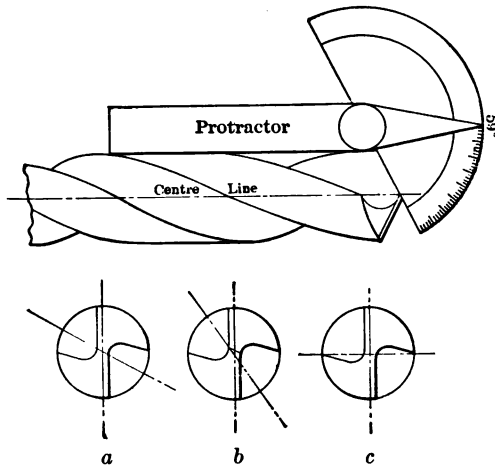


FIG. 45.

be properly cleared or backed off, and should be of equal length. The angle for iron and steel is from 59 to 60° , and for brass from 75 to 76° —a greater angle in the latter case because of the tendency of the drill to hook into the softer metal, especially as the drill is about to break through the work. The angle of the point is a sure indication of the lip clearance, as illustrated at *a*, *b*, *c*, in Fig. 45. Too much clearance, as shown by *b*, will produce irregularly shaped holes.

Fig. 46 indicates the results of improperly shaped grinding. One lip is much longer than the other, hence the two edges are at different cutting angles and only one lip cuts, making it impossible to drill holes anywhere near the size. Another thing that gives considerable trouble is carelessness about the point of the drill. It must be sharp, or else, no matter how keen the outer parts of the cutting lip may be, the drill will not work without considerable pressure,

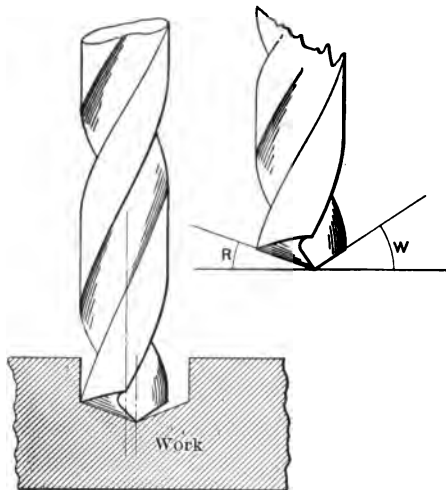


FIG. 46.

which in extreme cases tends to crush the drill. Another small thing, but very important, to observe, is the starting of the drill. If it runs out of center before it begins to cut the full diameter of the hole, the drill should be drawn over by gouge-chiseling the countersunk portion. This is more important in holes that are to be rebores, for it is desirable that equal metal should be left on all sides for the next succeeding bar or cutter. In every instance where accurate drilling is desired, it is advisable to drill a small hole first, as in Fig. 47, as the large drill will follow

more accurately. It also relieves the point of the large drill from acting as a pivot, and a hole of more exact diameter is obtained.

Fig. 48 shows a farmer or straightening drill, used successfully on cored holes. This is also available as a common bit for lathe work, by boring the work to a size just deep enough for the drill to enter, and by using the tailstock feed.

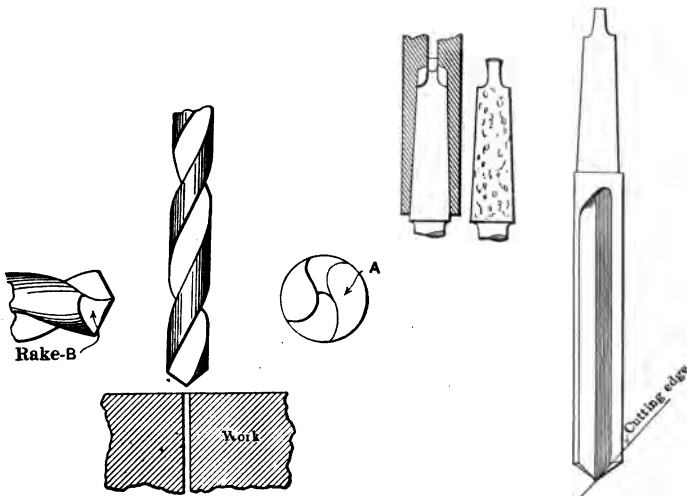


FIG. 47.

FIG. 48.

Another small thing that defeats good work—and the chance for promotion of many mechanics—is shown in the upper left-hand corner of the same illustration, where a little speck of dirt or a small chip came between the drill shank and the socket and made a depression in the drill shank every time the latter was driven up into the socket, until the shank had a pock-marked appearance. It is just as important that the shank of the drill should fit the socket of the drill press as it is to have the center of lathes fit into their respective places.

TABLE OF FEEDS AND SPEEDS FOR DRILLS

Size of Drill	Rev. per Min.	Feed per Rev.	Feed Rev. per M.
1"	380	.005	200
$\frac{3}{4}$ "	180	.007	143
$\frac{1}{2}$ "	110	.010	100
1	75	.014	75

The accompanying table shows the speeds at which the drills may be run. As to the feeds, remember that this depends entirely on the speed at which the drill rotates, and that to get the best results with a drill the highest speed possible for each particular size of drill is essential.

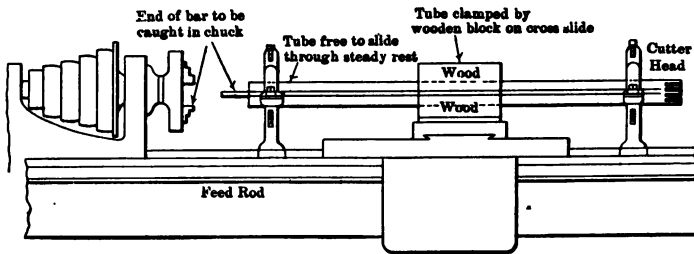


FIG. 49.

In many cases it is desirable to bore holes of small diameter, but of great length, which extend through the entire length of a tube, such, for example, as core barrels for rock drilling, where the tube is from 10 to 14' long and as small in some cases as 2" in diameter.

Fig. 49 will give an idea of the method by which such holes may be bored with very satisfactory results, and in Fig. 50 the boring bar is shown in detail. The bar is made up of sections, say 3' long, each so constructed that they can be joined together into one long bar. The work is supported in the lathe by two steady rests and is clamped to the carriage of the lathe by means of wooden clamps,

specially constructed to suit each individual case. The steady rests are only used to guide and support the tube as the carriage advances, carrying the tube with it. The end of the tube is first bored to a depth of about 2" with the ordinary boring tool, and made the required size. The bar is then inserted until the cutter head reaches the bored end of the tube, which the guide ring on the outer end of the head should fit nicely. The tube is then clamped to the carriage, supported by the steady rests, and the other end of the bar is held by the lathe chuck. Allowance should

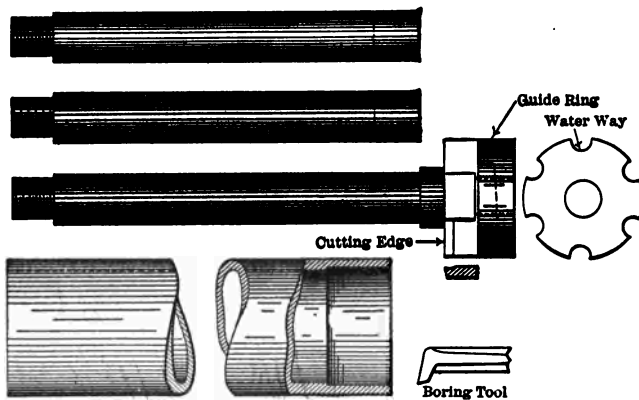


FIG. 50.

be made for the tube to travel a distance equal to the entire length of one of the boring-bar sections. When the tube is advanced this far, one of the sections of the bar is unscrewed and laid aside and the chuck engages the end of the next section, and so the work proceeds until completed. It should be observed that the face only of the tool should be used as a cutting edge, while the outside acts simply as a guide.

In Fig. 51 is another common type of boring tool more generally known as a counterbore, but it is used to a great

extent as a boring tool proper. It is important that there be two cutting edges, to balance or equalize the resistance and obtain round holes. Too often we find it used as a fly cutter, as shown in Fig. 51, without the advantage of speed which is essential to the success of a fly cutter. When the cutter takes up its work, the resistance due to the chip tends to push it away, and this strain is carried entirely by the bushing or guide pin of the bar,

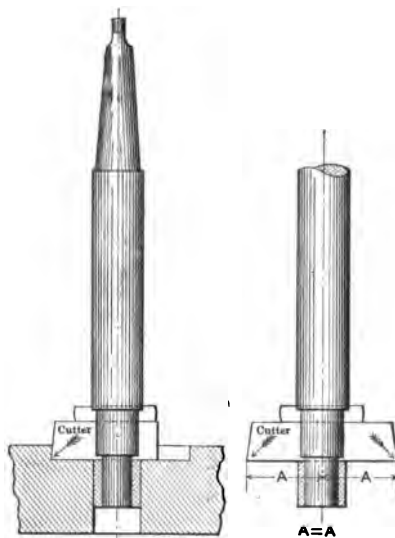


FIG. 51.

which results in the lapping out or uneven wearing in the hole. This means only one thing—the counterbored part will neither be round nor of the size intended. When a piece is irregular in shape, and in cases where the boring mill is not available, the drill press must be converted into a vertical mill. The work is clamped to the table of the drill press and the boring bar is carried by the drill spindle at its upper end and is guided at its lower end by a bushing in a hole at the center of the table.

QUESTIONS ON DRILL PROCESSES

Give sketches and description of method of drilling very deep holes of small diameter. How is the boring bar constructed? How is the work fed to the boring tool? For what are the steady rests used? How is the cut started?

What should be the angle of the lips of a drill with the longitudinal axis for cutting iron and steel? For brass?

What is a sure indication of the lip clearance on a drill? Give sketches illustrating this clearance, as well as description.

What is the effect of too much clearance?

Give sketches showing result of improper grinding of drills. Explain same.

What is the result of using a drill with a thick point?

BORING TOOLS.

If a drill runs out of center in starting a hole, how may it be drawn into center again?

How should you start a drill where very accurate work is required?

Give a sketch of a "farmer" drill, and tell on what class of work it is used.

Give a table of feeds and speeds of various sizes of drills.

CHAPTER VII

PLANERS AND SHAPERS—PRACTICE

PLANER PRINCIPLES

Their proper classification. Fundamental principles. Clamping of work. Strains, their action on work. Feeds and timing of same. Setting up tools. Appliances for planer and shaper for different types of work. Value of parallelism between the cross rail and platen. Methods of proving parallelism. Method of proving accuracy of vise. Order of handling work. Apron and its function.

IN beginning work on planer, first study the work you are going to do. Plan the method which will bring the result you desire. To do this you must get your working faces. Different metals, however, require different methods; for instance, cast iron will need different chucking or clamping on bed of planer than wrought steel. Why? Because the nature of a casting is such that it has certain conflicting strains and tensions upon it, due to the outer surface becoming chilled from contact with wet sand and air while the inner part is still warm and expanding. This places a strain upon the scale or skin of castings. The removal of this scale from any side allows it to adjust

FIG. 52.

		Ways (C. I.)	Platen (C. I.)	Work Rack (C. I.)				
		Bull wheel (C. I.)		Saddle (C. I.)	Head (C. I.)	Apron (C. I.)	Tool post (Steel)	Tool (T. steel)
		and Pinion (Steel)		Feed screw cross (Cru. steel)				
		Feed mechanism (Steel and C. I.)		Feed rod vertical (Cru. steel)				
Legs (C. I.)	Bed (C. I.)	Housings (C. I.)	Cross rail (C. I.)	Top rail (C. I.)	Elevating mechanism (Cru. steel)			

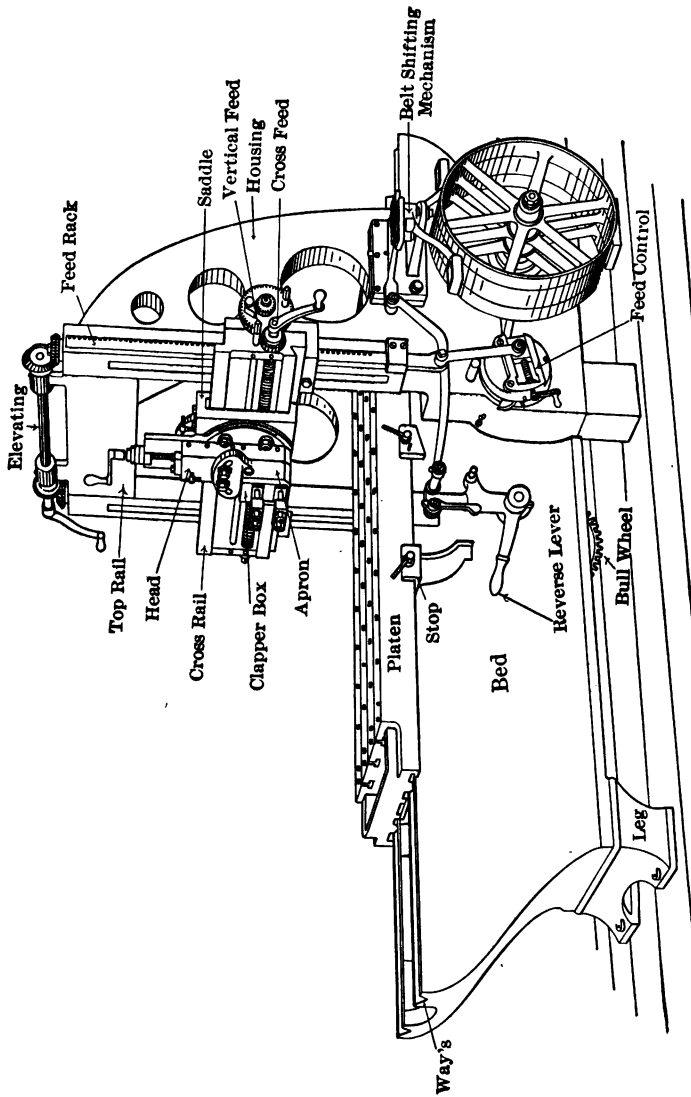


Fig. 52.—C. A. Gray Planer.

itself to whatever strain is brought to bear upon it, and it will not be a true surface; hence, to get accurate results in

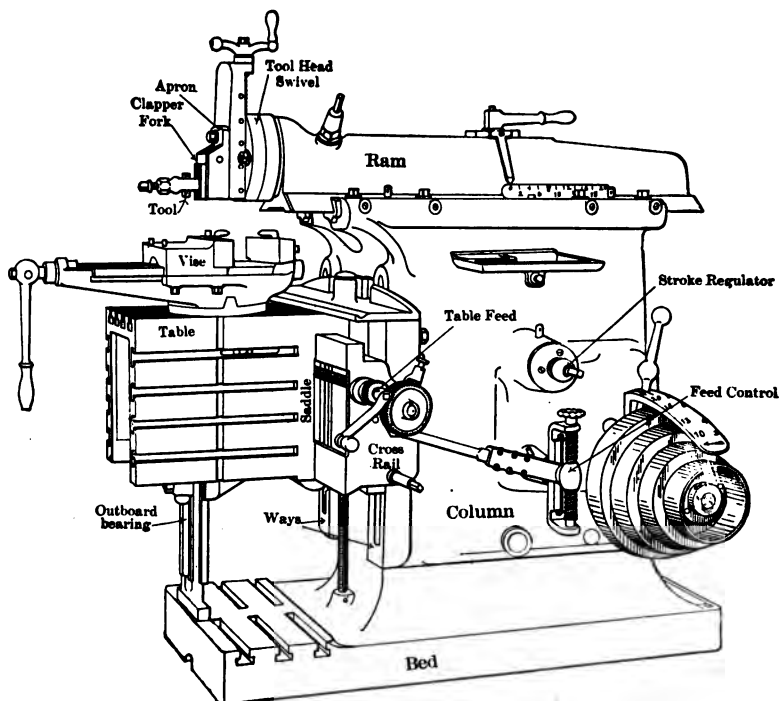


FIG. 53.—Gould and Eberhardt Shaper.

Bed (C. I.)	Box column (C. I.)	Transmission cone and shaft						
		(C. I.)			(Cru. steel)			
		Ways (C. I.)	Cross rail (C. I.)	Saddle (C. I.)	Tables (C. I.)	Vise (C. I. and steel)	Work	
		Feed screw (Cru. steel)						
		Ram (C. I.)	Tool head (C. I.)	Apron	Clapper box (C. I.)	Tool post (Cru. iron and steel)		
		Elevating screw (Cru. steel)						
		Main spindle (Cru. steel)	Bull wheel (C. I.)	Rocker arm (C. I.)				

planing castings, rough out the work all over, and afterward finish. This same law will hold good in machining castings on planer, shaper or lathe,

There is nothing new under the sun, so to keep the interest in the old things alive, it behooves us to present them in a new way, and from past experience I am led to the conclusion that the things which the writers of our machine shop treatises think too trivial to make note of are the very things our mechanics want to know about and are interested in. The little things of life make up the sum total of existence, and many mechanics have dated their downfall from that little speck of dirt which was too small to attract their attention. Admitting that present-day demands in commercial production have in a measure relegated the planer and shaper to the back numbers among modern producing machine tools, yet they are factors not to be discounted, and the mere shifting of a belt lever and setting of stops does not constitute a planer hand.

Another point, small as it may appear, so small in fact that it is commonly ignored, is the point at which the feed of the planer tool takes place; is it of any importance? Let us see. The resistance of the cut or chip to the tool is granted; there are two deflections of the tool, the horizontal, which tends to push the tool back from the chip, and the lateral, which tends to push it away from the work, sidewise.

This lateral deflection or spring is at right angles to the plane of the cutting edge, as illustrated in Fig. 54. This means that the tool does not cut its full feed, but springs away from the work, and this necessitated the design of the tool box, as it is to-day, to lift on the return stroke, and ride free. If the feed takes place at the wrong point the tool has to drag back over the metal that has not been cut, and the wear on the tool is proportionately increased. The feed should take place between the point of reverse and the beginning of the cut, enough distance should be allowed in setting the back stop to insure the full feed, and if a little air is cut, from which no chips can be seen, it will

pay in saving of the operator's time in grinding and re-setting of tool.

Occasionally the platen of the planer should be trued, because the center is more often used than the ends, and repeated clampings in this one spot, the draw on the bolts to hold the work, and the hammer blows occasioned thereby create a flow of metal which tends topeen the platen and make it high in the center.

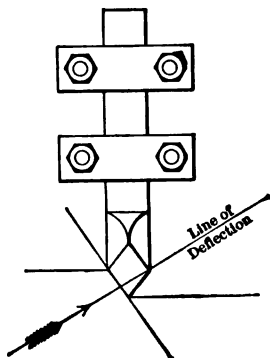


FIG. 54.

There are many devices for clamping work, but these again are only secondary; the prime feature to be observed is to have the work clamped without spring.

Thin shims or wedges should be used immediately under the clamps, if the work does not bed itself on the platen or working surface.

In clamping, another thing too lightly considered is the fulcrum for clamp. In common practice this is more tightly

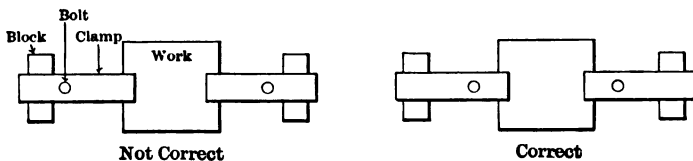


FIG. 55.

clamped than the work itself. Fig. 55 will illustrate clearly my point.

For very thin work a good method of clamping may be found by gashing in each end of the work with a milling saw, as in Fig. 56. Another convenient appliance is illustrated in Fig. 57. It acts as stop and clamp, and is cheap construction.

The pair of centers which belong to every planer is not used to the full extent of their usefulness, as they are useful for more than circular work. I have found them very convenient for all kinds of rectangular work that ordinarily is done in the chuck, and it is more economical, for when

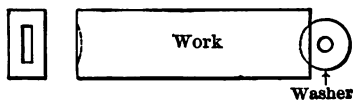


FIG. 56.

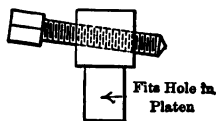


FIG. 57.

once set up the parallelism is assured. This is not the case in the chuck, where reliance must be placed on the skill of the operator each time the face is changed, because in most cases it is impossible to bed the work on the bottom of the chuck, parallel strips being used, thus multiplying the chance of error by 4, namely, the bottom of the chuck, the bottom of the parallel, and the top and the bottom of the work itself. If any doubt exists in the mind of the mechanic as to the accurate alignment of the centers, all that is necessary for him to do is to turn the work end for end and he is assured of parallelism, Fig. 58.

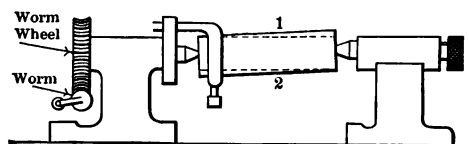


FIG. 58.

Side 1 is planed, after which it is turned end for end upside down, and 2 is planed. The illustration is, I think, sufficiently plain to all.

A device for planing arcs of different radii can be cheaply and quickly built and is a very convenient fixture, and one that will be found useful in very many cases.

The diagram shown in Fig. 59 will illustrate the device.

Plate No. 2 pivots on center pin of No. 1, *a* and *b* being machined surfaces for flat guides. The arm *E* is clamped to bottom of cross rail of planer, and the slot in *E* fits over bronze box *F*; as the platen travels, the plate No. 2 is given rotating motion, and the radius of the arc is changed by changing angle of arm *E*.

One more point before concluding, and that is the lax methods of calibration on a planer, especially on work

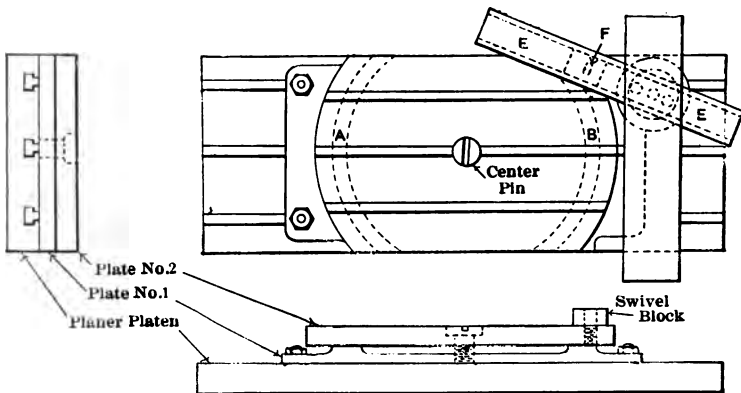


FIG. 59.

clamped to the platen. It depends entirely upon the skill of the mechanic how accurately he can read the lines of a 6 or a 12" inch scale in measuring the height of the work. Small measuring pieces can be filed and micrometrically calibrated and these used to bring the tool down to the required height, and these can be kept as standard height gauges for all time. See Fig. 60.

And last, but not least, the mechanic does not start work without breakfast, hence he should not expect the machine to start without oiling; it is this which gives efficient energy to the inanimate as food does to the animate. Also, a tool designed for lathe work has too

much clearance for planer work, 3° being the maximum clearance for planer tool: the heel gives strength.

The mere doing of the work itself is to the workman what dessert is to a good dinner. It is the study of conditions and methods of doing the work that is really the substantial meal, and the valuable man is he who can plan these methods and look after the necessary conditions. The cheap man can carry them out. This chapter will deal with conditions whose understanding is essential to

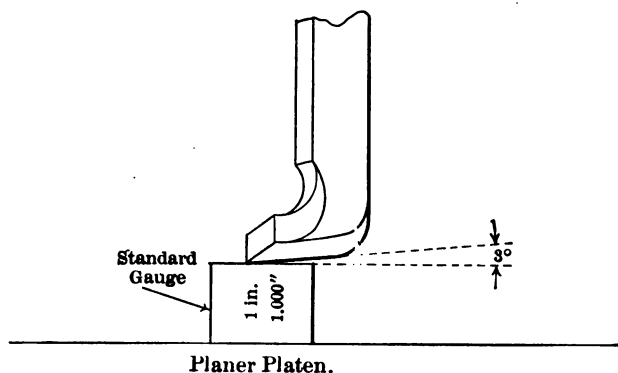


FIG. 60.

the mechanic, be he machinist or engineer, and we will first deal with planer and shaper.

The planer is the simplest of machine tools to manipulate, and one can obtain fairly good results with limited knowledge of the tool itself. The planer is designed to take in a wide range of work with respect to size and weight, and the first important point to observe is that conditions change every time the cross rail is raised on the housings to accommodate the machine to varying heights of work.

Observe that the means of raising the cross rail is by screws at either end, these screws receiving their rotary motion by means of bevel gears engaged from a common shaft, Fig. 61. This method does not give assurance that

side only, and by means of the handle the cross rail can be raised the slight amount necessary.

A more accurate way to obtain parallelism is shown in Fig. 62. Use a round rod with convex end, leaving only a point contact; bring this rod down by means of the screw which operates the tool slide, to within a few thousandths of the bed and, by means of a piece of hard paper such as white envelope, get contact, using the paper to feel the contact, and proceed as before.

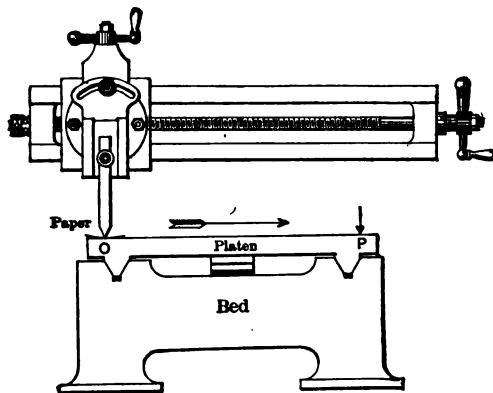


FIG. 62.—Method of Testing for Even Setting. Contacts at *O* and *P* should be the same.

This, of course, refers to work that is clamped directly on the bed, but in many cases the work is done in a chuck clamped to the bed, when other conditions enter which are not taken care of by this means, although this should be the first condition looked to. In chuck work on a planer, or vise work on a snaper, the movable jaw is constantly subjected to wear, and is used only as a clamping piece; so the first important point to examine in this case is whether the stationary or dead jaw of the chuck is at right angles to the plane of the tool travel. This is done as shown in Fig. 63, by delicately clamping a true square in the chuck and getting contact on the extreme

end of the square-blade as we did on the planer bed. If an error exists, the jaw should be taken off and ground to meet the error, or packed with thin sheet metal until the error is corrected.

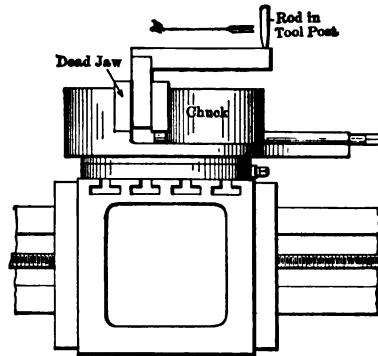


FIG. 63.—Testing Accuracy of Travel of Shaper Tool.

With the best of conditions, however, unless the worker follows his work in logical sequence, he will have trouble in planing or shaping a piece of work square and parallel. To better illustrate what difficulties are to be met with, we will plane the simplest piece of work, a bar of cast iron

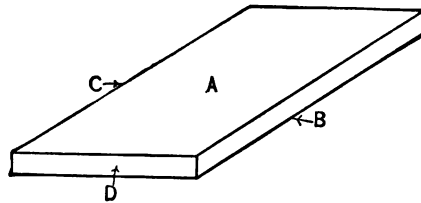


FIG. 64.—A Parallel Planer Strip.

designed for blocking purposes and commonly called a parallel strip. It must be remembered that a certain amount of draft is given to all patterns, to enable the molder to draw them from the sand, hence the castings will not have parallel sides to start with, Fig. 64.

In machine work of this character one of the largest flat surfaces, *A*, will be machined first and used as a working face. The face *A* is then clamped against the true or dead jaw of the vise, and the edge *B* machined, after which the opposite edge *C*, is finished, keeping the working face, *A*, always against the dead jaw. Lastly, *D* is planed.

This order will insure accurate planing. The reasons for this method are as follows: We know that the sides of the castings are not parallel, to start with, we know that the movable jaw is constantly subjected to wear and, in clamping work, as soon as the pressure necessary to hold

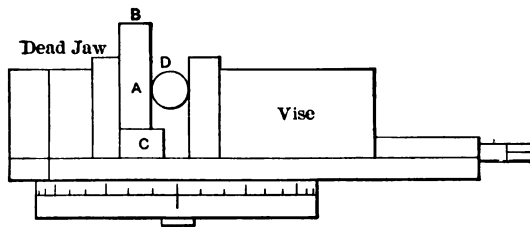


FIG. 65.—Device for Getting True Work in a Planer Chuck.

the work is brought to bear upon it, that it raises according to the amount of its wear.

This tends to lift the work with it. The jaw will, invariably, conform to the irregular sides of the castings, so that, as one flat side is machined, and we attempt to machine the opposite side, this difficulty always confronts us. A good method for overcoming this tendency to raise the work is to insert a round rod, as shown in Fig. 65, when any tendency to rise on the part of the movable jaw creates only a rolling motion on the rod, and does not affect the work.

The function of the apron *A*, Fig. 66, is too often ignored, sometimes intentionally, but more often from ignorance. That it has a distinct use is apparent from its careful construction. The tool holder proper, indicated by *B*, being

pivoted on the rod, *F*, provides for the lift, primarily to avoid wear on the tool during the return stroke of the machine; this will be obviated in some degree if the machinist gives proper attention to the timing of the feed of the tool, which should take place just after the return stroke is completed and before the tool starts to cut, not during the return nor during the cut. This means that

there must be a good clearance between the work and the point of reverse. It is only another little point, but one that, if observed, makes it possible to do much work with little grinding of the tool. The stroke should be enough longer than the work to allow for tool feed, the greater clearance being given necessarily at the starting point, and only enough at the finish to allow the tool to clear the work.

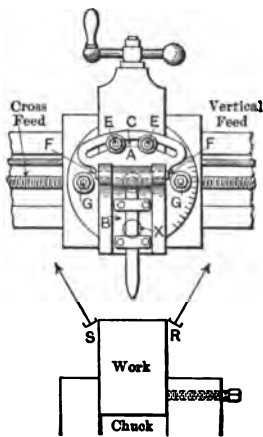


FIG. 66.—Setting for Planing Vertical Sides: slack up bolts *EE* and set the head as indicated by the arrows. For dovetailing, loosen bolts *GG* and turn the head the required number of degrees.

The reasons now being clear why the tool box has lift, a word about the apron, of which the tool box is a part. It is so arranged as to swing on a pivot which is located at about the center, *X*, of the box, *B*; from this center the arc, *C*, is described.

In vertical planing, the apron is moved right or left according to which side the machinist is working upon. This moving from the vertical position changes the line of center of the tool, so that in raising the tool it rises away from the work and relieves it from drag on the return stroke. If there was no spring or deflection in the tool and work, this would not be such a serious matter, but no

matter how carefully the angle of cutting edge has been studied, when the tool starts to do its work there is considerable spring of the tool away from the work, and for this very reason, after the finish of the cut this resistance ceases and the tool would ride hard on the work during the return stroke. Fig. 66 indicates by arrows the direction of apron throw, planing to the right, *S*, and to the left, *R*.

The next important step, after seeing that conditions are right, is the clamping of the work upon the machine. If a piece of work was laid on the platen, with no stops or clamps to hold it, and the machine started, as soon as the tool came in contact with the work it would shove it along bodily, hence the first step should be to see that proper stops are placed to resist the cutting force, and as there is really no tendency on the part of the tool to raise the work, only sufficient clamping is necessary to keep it solid. The work should be well wedged if it does not rest level on the bed, especially under the clamps, so that there will be no spring of the work due to clamping, and in every case the clamps should be relieved of most of their strain before taking the finishing cut.

The whole tool head of the planer or shaper swings on a common center also, and the graduation on the circular part indicates degrees, which enables the operator to plane at any angle he desires for dovetailing.

Here another little thing is worth noticing: don't take for granted that, when you have set the head over to the desired degree, it will plane that angle, for very often it does not; the side may be worn, and not straight; and again the lines of graduation are quite wide, so that it is difficult to get an accurate setting. When it is important that the angles on both sides of the piece should be alike, the proper course is to make allowance for turning the work, side for side, and allow the head to remain in its original setting.

To better illustrate this, let us take a set of V-blocks and plane them from the rough.

V-blocks are used as master appliances on planers, for holding bars, piston rods, etc., and must of necessity be accurately aligned and planed on the same line. Fig. 67 will give a clear idea of their proportions. The full set, either two or four, are clamped to the planer and the side *A* planed, after which they are reversed, and the opposite side, *B*, planed.

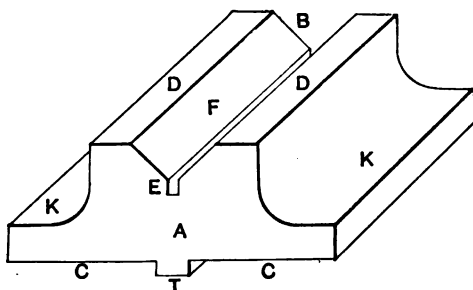


FIG. 67.—V-block for use on Planer Bed.

Now the sides *A* and *B* are planed on all the blocks. They are all gripped together in a chuck and the side *C* planed, leaving the tongue *T* to fit the slot in the platen accurately. The blocks are then placed on the platen in their proper groove and clamped on the sides *KK* and the edges *DD* planed. A square-nose tool is used to plane the slot *E* for the tool to run out. Lastly, for the sides, *F*, the tool head is swung round to 45° , and one side planed; then the clamps are loosed and the work turned to plane the opposite side of *V*. This not only insures the same angle, but will bring the *V* in the center of the block, central with the tongue, which is an advantage in setting the tool for many pieces of work.

Fig. 68 will give some idea of tool setting, and clearance. The planer tool has very little clearance, as it needs the

heel well down to sustain the cutting edge during the performance of its work. The apron also should be run well down and the tool gripped short to avoid spring in the shank of the tool. As indicated at the left the tool should be set at right angles to the face of the work. When so set, any side motion will let the tool draw away

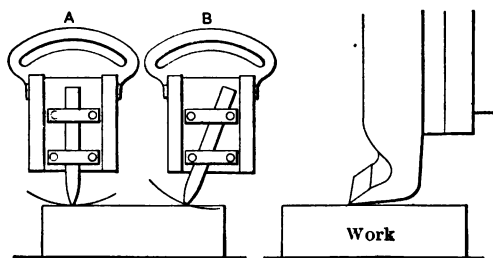


FIG. 68.—Method of Setting Tool with Proper Clearance and at Right Angles to the Work.

from the work, as at *A*. If set as at *B*, the side-wedging action of the cutting point drags the tool into the work and makes it difficult to get a true surface.

QUESTIONS ON PLANERS

Make a sketch of a tool without either side or back rake and explain its action.

Is such a tool correctly ground?

What class of tools do you study first?

Should a planer tool have much clearance?

State the smallest amount permissible.

Should there be a great amount of top rake on a planer tool?

Are you permitted to give considerable side rake?

State a second reason why a planer tool is apt to bite into the work, and explain its action in so doing.

What may cause a "chattered" surface, on planed work, besides springing of tool?

Which is the better for producing smooth work on a surface, the rack and gear, or the worm-drive planer?

Give a sketch showing how a planer tool may be designed to avoid "biting" into work.

Give a sketch showing the ideal form of finishing tool.

What is the distinctive difference between a planer and a shaper?

Name and describe several different kinds of shapers.

How is the spring of the work away from the tool taken care of in the shaper design?

What is the function of the apron?

How is angular work done on a shaper?

Describe the reversing mechanism on planer and shaper.

How is quick return obtained? Name several ways and the value of each.

CHAPTER VIII

LATHE PRACTICE

LATHES

Different types and their classification. Main spindle centers and their true value. Taper turning. Rule for taper turning. Thread cutting. Rule for thread cutting. Method of figuring rules. Value of centering work true. Value of facing work first. Tumbling gears, their functions. Setting of tools. Grinding of tools.

Principles of Construction and Proper Method of Handling. The first essential in doing a master's work is to know intimately the tool upon which you are going to do the work; know its relation to all others, their relations to each other, and their proper function, so that an intelligent result is obtained.

In order to acquire this knowledge, the accompanying chart will prove valuable to the beginner. It shows the building up, step by step, and the relation of the parts to each other, as well as the names commonly applied to each part. It is also well for every mechanic to be thoroughly familiar with the materials of construction, for through this knowledge he trains his judgment to be sound and also gets a sense of proportion and the eternal fitness of things mechanical.

Different Types of Lathes. The *hand lathe*, having no carriage or power feeds, where the hand tool is held on a rest, and no thread cutting facilities other than a hand *chaser*.

Engine Lathe. A power machine, with power feeds, and several cutting attachments, tool carriage and simple and

compound rest. They are enumerated thus, as *single-gear*ed lathes, wherein the power passes through a single of gearing.

*Double-gear*ed Lathes when it passes through a double train of gears, and is used for heavier work.

*Triple-gear*ed Lathes when it passes through three trains of gears and used for still heavier work.

*Quadruple- or Double-compound Gear*ed Lathes.

Assuming that there is no end thrust or lost motion in the bearings of the lathe spindle, the most important thing to observe before beginning a piece of work is that the centers fit in their respective spindles. They should be taken out and brushed clean, not wiped off with a piece of cotton waste, which leaves lint hanging to parts of it, but with a small brush, such as jewelers use, and which should be a part of every good mechanic's kit; a reamer of the same standard taper as the center should be run around in the spindle by hand, to pick up any particles of dirt or foreign matter which may have been lodged there.

Being satisfied on that point, the next step of importance is to prove the live center by running the back of a tool up to it and holding a piece of white paper underneath. Note the slightest variation of the face of the center while running, for it is essential that it should run perfectly true, if accurate work is expected. The live center is usually soft, for there is no frictional wear on it, its function being that of a centralizing support only; being soft, it has the added advantage that the operator can true it by turning, without unnecessary delay.

When necessary to true a center, make it a rule never to use a file for finishing, but tool it true, and this, by the way, is a good rule to follow on all work. It is an utter impossibility to file work round in a lathe, if for no other reason than that you cannot maintain equal cutting pressure throughout the entire length of the file stroke. For turning the center there are several tools which might

be used, but perhaps none is more efficient than a side tool used as in Fig. 70 by running the lathe backward and having the side tool set level.

The third step of importance is the alignment of centers to insure parallel turning. Ordinarily, the operator will

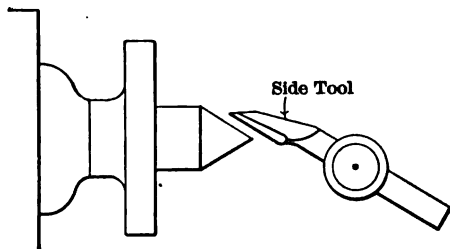


FIG. 70.—Use of a Side Tool for Truing the Live Center.

push the tail stock up until the two centers meet and line it by eye, but this is only an approximation and depends entirely upon what kind of an eye the operator has. A sure way to test the center for alignment is shown in Fig. 71.

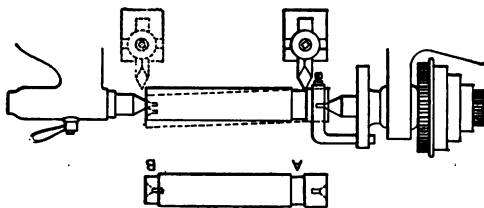


FIG. 71.—Testing for Alignment of Centers. Dotted lines show piece as held off center while moving the tool over for the second cut.

The work itself, if it is to be a plain cylinder or piston rod or piece of shafting, can be used for the purpose, or any old mandrel or piece of scrap rod, always to be found around a shop, will answer. The piece is placed on the centers, the tool brought up to within a short distance of the carrier, and a light cut taken just wide enough to allow a

micrometer measurement to be made; the work is taken from the centers and the carriage moved down to the dead center end of the work without changing the cross travel of the tool; the work is then placed on the centers and a cut taken on the extreme end of the rod; if the microm-

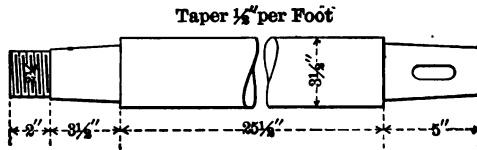


FIG. 72.

eter measurements are alike the centers are properly aligned. Any adjustment that is necessary is easily made by means of the screws on the side of the poppet head. After adjustment the same testing process should be repeated.

Now we are ready to be busy, and will take for example the piston rod of an engine, and go through the various operations from roughing to finish. Assuming the rod to be of forged steel, to finish to size as indicated in Fig. 72. First it is important that the work be carefully centered, no matter how much stock is left for finish, for the nearer the cutting resistance comes to being uniform the nearer round will the piece be turned. Fig. 73 may be of

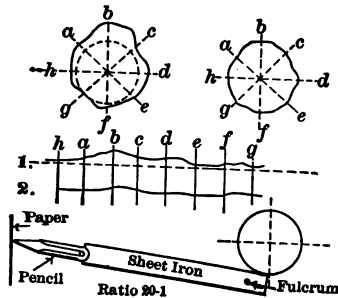


FIG. 73.—Test for Inaccuracy of Turnings.

interest as showing what really takes place in turning; it shows the rough forging, 1; also the piece after turning, 2, and the bottom figures on the sketch illustrate the tool and the method of obtaining the record lines. A long light lever has a point of contact at one end near the fulcrum,

which bears against the periphery of the work; on the other end is a lead-pencil attachment with the point bearing against the card indicated; the card travels at the same rate of speed as the work, but in the direction of the axis of the work; any unevenness in the surface of the work raises or lowers the point of the pencil, and as the ratio is as great as 20 to 1, the variation in the line is quite marked.

Starting at the arrow and developing the line of circumference in a straight path, we will get a line like (1). After turning and repeating the process, the developed line will look like (2).

The centers should be large enough not only to carry the weight of the bar, but to withstand the crushing effect that takes place during the turning; in a bar of this size the outside diameter of the center when finished should be about $\frac{1}{2}$ "—about one-seventh the diameter. Both ends should then be faced; this is important as one of the first operations before turning, as the following reason should be sufficient to prove: When the turning tool starts to cut, the resistance due to the chip creates a crushing force on the dead center; in other words, the center resists the tendency of the tool to push the work away, hence unequal bearing on the center is affected unequally, as the smallest surface will be affected the most, hence the center will wear out of round. Fig. 74 will better illustrate the point.

A roughing cut is next taken, and here the tool conditions must be studied; the cutting angle of the tool should be about 55 degrees, the tool caught short to reduce spring and set at right angles to the plane of the work, thus eliminating the possibility of the tool being drawn into the work during the cutting process, as indicated in Fig. 75.

After roughing the work, the next step would be the cutting of the thread for the nut. As the thread cutting requires more skill than plain turning, the advantage of this is, that if any accident happens by which the thread

end is spoiled, the time required for turning and finishing the whole rod and fitting tapers is thereby saved.

Modern lathes have tables of chain gears for the different threads screwed to some part of the machine, but the

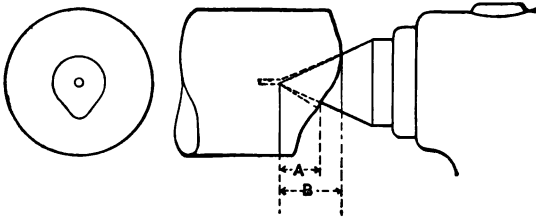


FIG. 74.—Showing the Result of Turning before Facing the Ends. *A* is the length of bearing on one side, *B* on the other. The wear at *A* will be greater on account of the smaller surface to resist crushing.

thinking engineer will admit the wisdom of knowing how to figure the different gears without depending upon the table. A simple method is here given, which will enable even a novice to calculate the changes.

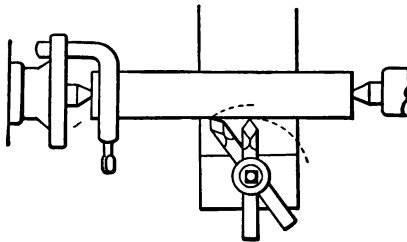


FIG. 75.—Proper Setting of Diamond Point in Lathe.

Thread cutting is regulated by the different ratios of speed between the main spindle or cone and the lead screw, hence we find the number of threads per inch on the lead screw and use this as the numerator of the fraction or ratio, and the number of threads to be cut as the denominator; for example, the number of threads per inch on

the lead screw may be 4, and the thread desired on the piston rod, 8, then

$$\frac{\text{threads on lead screw}}{\text{threads desired}} = \frac{4}{8}$$

If we had a wheel with four teeth and one with eight, we could cut the thread with them, but as that is impossible, we multiply by some number, even or odd, according to the pitch of the gear on the lathe we are running. On the majority of the lathes, the wheels run in even numbers, such as 24, 28, 36, 40, 44, 48, 52, and so on, hence 4 or 8 would be a good number to multiply by, and we have

$$\frac{4}{8} \times 8 = \frac{32 \text{ lead screw gear teeth}}{64 \text{ stud gear teeth}}$$

Again, on a lathe where the wheels run, as in some cases, 28, 35, 42, 49, 56, 63, 70, 77, 84, 91, 98, etc., 7 or 14 would be the number by which to multiply. Then

$$\frac{4}{8} \times 7 = \frac{28}{56}$$

A fibrous material such as soft steel or wrought iron should be cut with a lubricant, which serves a double purpose—to keep the cutting edge of the tool cool, and to reduce friction between chip and tool. Soda mixed with water will prove effective, soda being introduced chiefly to prevent rust on the machine parts.

A word about the tools: the cutting edges should be kept as keen as possible at all times, by oil stoning. The

NOTE—The formula explained above holds good on all lathes in which the main spindle and stud are run at the same ratio; where the ratio changes and stud runs half as fast as the spindle, multiply the numerator by two.

thread tool should be set absolutely level and on a plane with the center of work. If U. S. standard is called for, it means the flat top and bottom, a thread that has decided advantages over the V-thread in that it leaves the work stronger at the root, and, due to the flat, is an easier thread to cut, because the real difficulty in thread cutting is with the point of the tool. The flat surface which should be on

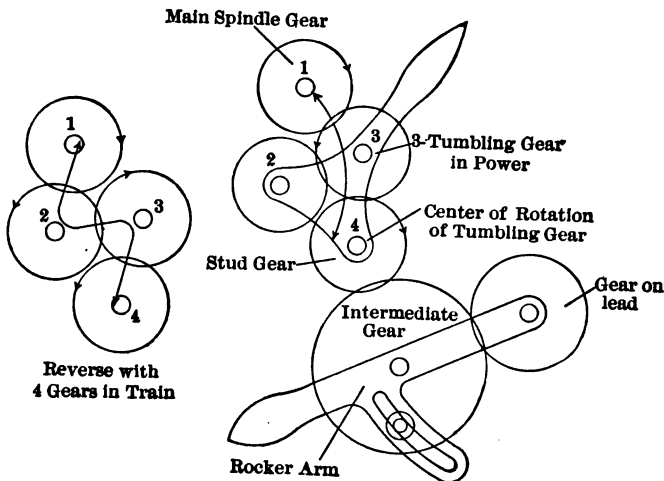


FIG. 76.—Arrangement of Gears for Thread Cutting.

the end of the thread tool for each different size of threads is figured by taking one-eighth of the thread pitch; for example, for 8 threads per inch $\frac{1}{8}$ of $\frac{1}{8} = \frac{1}{64}$ = flat for 8 threads per inch; for 4 threads per inch $\frac{1}{8}$ of $\frac{1}{4}$ = flat.

The cutting speed and the cutting feed should be important to every operator of a machine, that he may know he is getting the maximum efficiency of the machine. This efficiency is determined in some shops by the color of the chips that drop from the tool, but this does not mean much to the mechanic who desires a basis for calculation.

In the first place, it has been proven by experience that

for roughing cuts, a slow speed and a fast feed are economical (understand, I am referring only to carbon steel, and not to the patent air-hardened or superheated steels that are coming into use, because lathes have not yet been built heavy enough for all-round work to get the highest efficiency of this steel, nor is this steel of much value for finishing cuts).

Cutting speed means the number of feet the shaving cut by the tool in a given time, say one minute, would measure if extended in a straight line. For example, if the lathe makes 30 revolutions per minute on work with a diameter of 4"; take a coil spring of 4-inch diameter with 30 coils and stretch it into a straight line and you would have the number of feet of cutting speed per minute. A 4-inch circle has $4 \times 3.1416 = 12.57''$ or 1.05' circumference, so that the cutting speed would be $1.05 \times 30 = 31.5'$ per minute.

Cutting feed means the thickness of the chip, or the travel of the tool in one revolution of the work.

A cutting speed of 28 to 30 feet per minute and a cutting feed of 30 revolutions to 1" of tool travel is efficient for work on soft steel.

The next step after cutting the thread is the taper; not every lathe has the taper attachment, hence the poppet head or tail stock must be used. The taper given is $\frac{1}{2}''$ per foot, and the following sample formula will give the throw over of the poppet head.

Find the taper in 1'', multiply by the length of the piece over all, and divide by 2'.

$$\frac{\frac{1}{24} \times 36}{2} = \frac{36}{24} \times \frac{1}{2} = \frac{36}{48} \text{ or } \frac{3}{4} \text{ inch,}$$

NOTE—The author uses an inch as the unit of measurement instead of a foot, because a great deal of the work is under a foot. Divide by two because the diameter is double the radius.

the throw of the poppet head. Remember, no matter how short the taper desired, the length of the whole piece of work is what is affected by the movement of the dead center out of alignment; the whole piece fulcrums on the live center, hence must always be taken into the calculations. If this rule is carefully worked and the head carefully moved, it will give an accurate result.

In shops where the rods are made in great numbers and kept in stock, a taper sleeve is used as a gauge for proving the taper as the operator proceeds with the work; in railroad repair shops usually the screw head and piston head are used for fittings; if properly fitted, $\frac{1}{8}$ " is ample allowance for drawing home.

There is left now only the plain turning of the rod, and in the modern shop of to-day the rod is turned only to an approximate size within, say, $\frac{1}{32}$ ", and is then ground to standard size on a grinding machine; if, however, there is no such machine in the shop, it must be turned to size, in which case a ring-gauge of standard size is used to follow up the cut. The tool should have just enough of a flat edge to cover the feed; for instance, if the natural feed were 60 revolutions of the work to 1" feed, we say the feed is 60, and if the tool was ground to a point, it would cut 60 threads, hence the flat on the tool should be over $\frac{1}{60}$ " to insure a smooth surface.

In Fig. 77, *A, B, C, D* represent different depths of cuts, and you will readily see that the line of cutting resistance is about the same, hence the power required to do one-quarter of the work as at *D* is the same as at *A*, where the maximum efficiency is obtained.

A, B, C, D, here represent cutting angles of the tool,

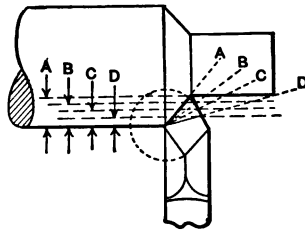


FIG. 77.—Correct Cutting Angle for Diamond Point.

A being the correct angle and B, C, D, incorrect, due to careless grinding of the operator.

QUESTIONS ON LATHES

What is a machine?

What is the first thing you should do when you start to use a machine?

What precautions must always be taken, in connection with the lathe centers?

How is the live center trued up?

Which center is hard and which is soft?

Is it good practice to use a file on lathe work?

What tool do you use for truing a center?

What is the third step of importance when starting a lathe?

How is it done approximately?

How is it done accurately?

Is it important that all work be centered true, regardless of the amount of stock to be removed?

Why?

What proportion of whole diameter of piece do you commonly make the center hole?

Should the ends of a piece be faced before starting to turn it?

Why?

What should be the angle between side faces of diamond point?

How should it be set in the tool post?

If you have a lathe furnished with a 6 per in. lead screw, and you wish to cut 15 threads per in., what gears of the following would you use—32, 36, 40, 66, 72, 80, 86, 90, 98?

At about what speed should tool steel be machined?

What is meant by the term "feed"?

Give the proper feed for cast iron.

Give the proper feed for tool steel.

A piece of tool steel $\frac{3}{4}$ " in diameter is to be turned in a lathe. How many revolutions per minute should the lathe make to give a cutting speed of 40' per minute?

Should the number of revolutions be reckoned while the lathe is running free or while the tool is cutting?

A piece of tool steel $\frac{7}{8}$ " in diameter is turned in a lathe at 168 revolutions per minute. Find the cutting speed.

A lathe has a feed rod turning at the same rate as the lead screw, while the carriage travels one-quarter as fast as it would when screw cutting. If geared for 12 threads per inch, and feed rod is used, what will be the feed?

In the preceding question, if the lead screw has 6 threads per inch, and the gears, 24, 36, 48, 72, were at hand, how would you gear the lathe? Give stud and screw.

Is it possible to get a perfectly accurate feed on a lathe with belted feed rod? Why?

If a lathe has three cones on feed rod, how many feeds are possible? How could you obtain more?

How would you cut a left-hand thread on a lathe with no tumbler gears?

What is meant by compounding lathe gears? Does this change the direction of thread, i.e., right or left hand?

A lathe has gears 32 and 64 for cutting 8 threads per inch. How could these be compounded to cut 16 threads per inch? Draw sketch of train of gears you would use.

CHAPTER IX

CUTTING TOOLS

TURNING TOOLS

Turning tools. Different forms and reasons for same. Leverage. Difference between planer and lathe. Tool angles of clearance and why. Correct rakes and angles. Setting of tools. Cutting force for different metals. Cutting speeds and feeds.

Cutting-edge Principles, Proper Angles, etc. Planer tools will first come under our notice as being the simplest and requiring the least skill in setting. You have doubtless observed that if the chip be unwound from the spiral shape it assumes in leaving the tool, and projected in a straight line, it is shorter than the surface from which it came. This is due mainly to the compression of the metal in the direction of the cut, and you will thus see the possibilities of saving power and strain upon the machine by giving proper cutting angles to the tools and reducing this compression to a minimum.

In Fig. 78, the cutting tool is at right angles to the work and without rake. It exerts its force in a direction nearly parallel to the surface of the work, and, having no side rake either, it simply does not cut, but shoves or crowds the metal forward, producing a chip made up of little splints. It cannot exert any force to lift or curl the chip.

This tool is wholly wrong, nor would it materially improve it to grind like the tool shown in the little sketch at the right, which goes to the other extreme, and would spring into the work. A tool must first of all be heavy

enough at the back or heel to resist the horizontal cutting force, and consequently should have very little clearance.

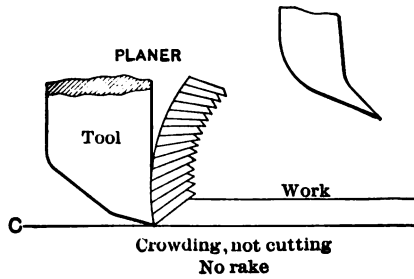


FIG. 78.

The 7° clearance shown in the lathe tool in Fig. 79 is too much for a planer tool, while the 3° of the lower sketch is as small as can be used safely. Theoretically,

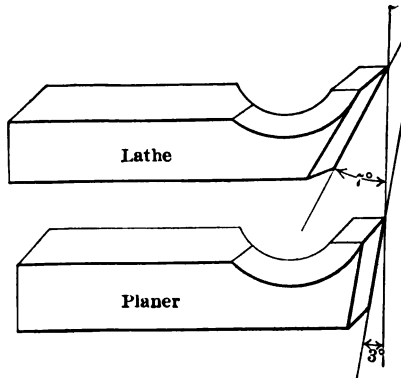


FIG. 79.

if the point, of a planer tool leads by only a thousandth or two, it will perform its function. There should be very little top rake on account of its tendency to make the tool dig into the cut; but this can be compensated for by giving considerable side rake.

Another reason why the planer tool tends to dig into the work is illustrated in Fig. 80. Point A in each sketch is the fulcrum. In the first sketch the tendency is for the tool to dig into the work in the direction of the arrow. This is not so serious as appears on the face of it, as planer tools are usually so stiff that they will spring but little and any error that might occur in the roughing out would be eliminated in the finishing cut. What many mechanics take as an indication of the spring of the tool is really due to the chatter of the planer; since a rack and pinion planer

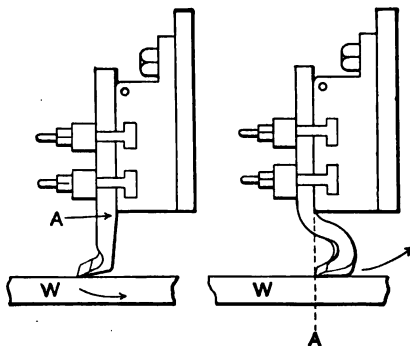


FIG. 80.

will frequently chatter after it has become worn, while in a worm-driven planer the lost motion is all taken up at one end before beginning the cut and the screw action does away with the chatter. To obviate any spring the tool may be designed as in the second sketch, Fig. 80, where the deflection due to the force of the cut is away from the work in the direction of the arrow.

The tool in Fig. 81 approaches the ideal for a finishing tool and gives the best finished surface of any that I have used on planer or shaper. It is made from a piece of ordinary tool steel and forged on the end in the shape indicated. It will be noticed that it has side rake instead

of being straight on the bottom; the line that comes in contact with the work is a little rounding.

We will now take up the subject of cutting edges of some of the many varieties of lathe tools, Fig. 82. Here

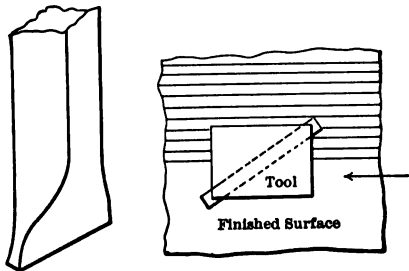


FIG. 81.

are shown a diamond point, a round-nose tool, a side tool, centering tool, thread-cutting tool, and cutting-off tool. We will first consider the diamond point, as it is more of a universal tool than any of the others. Before speaking

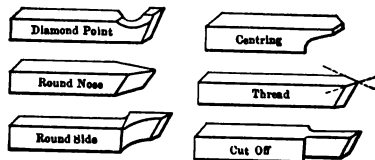


FIG. 82.

of rake, clearance of the setting of the tool, I want to call attention to the general form of the cutting edges, and the importance of maintaining the same throughout the life of the tool.

Fig. 83 will best illustrate my meaning. The tool is shown at the left with depth of cut, and ground so that the angle shall not be less than 55° . To the right is a tool in which the angle has been changed by grinding on both sides of the point, only because the machinist claims

that he is in a hurry and must make time on his work. But it will be seen that to do the same amount of work the line of cutting resistance is much greater in *b* than in *a*; showing loss in the efficiency in the tool and requiring more power to drive it after it has been ground. Nor is this the only reason why careless grinding will produce a loss, as I will proceed to prove.

This is true with proper rake, angles and clearances, but when the mechanic ignores all principles and is careless besides, it becomes much more serious because more

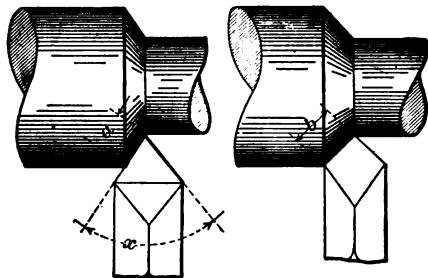


FIG. 83.—Effect of Grinding Tool to Improper Angles.

finishing will be required to make the piece straight. The nearer the cutting edge of the tool comes to being parallel with the axis of the work, the more power will be required to operate the tool.

It will be interesting to note what really takes place in turning, as shown in diagrammatic form in Fig. 84. Here is represented a piece of rough stock that is to be turned as indicated at the right. First starting at the corner line *A*, and developing the line of circumference *o* in a straight path, we will get a line like (1). After turning and repeating the process, the developed line will look like the line at (2). It will be noted that the second line is somewhat irregular, showing that even after roughing off, the surface of the piece has nearly all of the irregularities of the rough stock, though on a smaller scale.

This brings us to another important point, and that is the necessity of centering work as accurately as possible, for no matter how even the work may be on its circumference, if centered out of true, it will not be round after turning. Why? Because the thickness of the chip or shaving is not uniform, hence does not offer uniform resistance to the cutting edge, and the work will bend more at one point than the other. If the cut were uniform and offered the same resistance, of course we could expect round work.

The bottom figure on the sketch illustrates the tool and method of obtaining the lines. A long, light lever has a

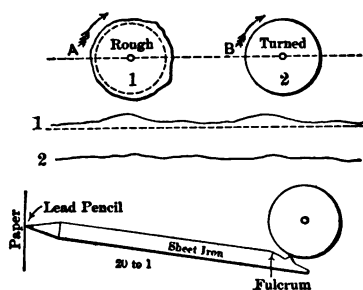


FIG. 84.

knife edge or point at one end, near the fulcrum, which bears against the periphery of the work. On the other end is a lead-pencil attachment, the point bearing against the piece of paper indicated, the paper traveling at the same rate of speed as the work, only in the direction of the axis of the work. Any unevenness in the surface of the work raises or lowers the point of the pencil and, as the ratio is great (20 to 1), the variation of the line is marked.

Fig. 85 illustrates an important point in setting the tool. The farther the cutting edge is from the base, or support, the greater will be the spring. Where this spring is possible,

the point is drawn down as indicated in the dotted line, and furthermore, will produce irregularly shaped work due to the variation in the resistance of cut at points where the tool digs in. This indicates the value of short leverage.

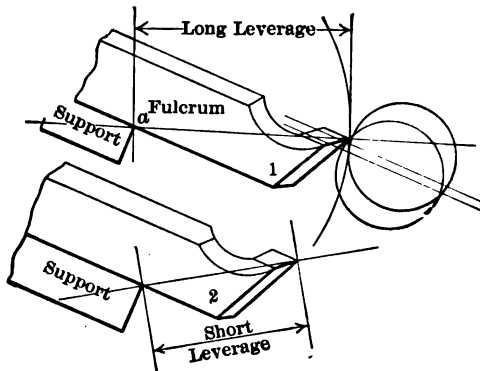


FIG. 85.

In Continental shops, and especially in England, it has become a recognized principle that the top of cutting edge of tool should not be higher than the top of the support, and to obtain its top rake the tool is harrowed out in

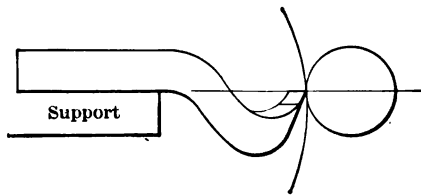


FIG. 86.

grinding. Sir Joseph Whitworth designed his lathes so that the tool set on the center of the work, and any vertical pressure deflected the tool away from the work, as shown in Fig. 86.

Next in importance to the leverage of the tool is the angle at which it is set in relation to the work. Referring now to Fig. 87, the tool is shown at right angles to the work, and will deflect away from the work, instead of causing it to dig into the work. If the tool were set as shown in the dotted position, it will be readily seen, that any slipping or deflection would carry it into the cut.

The third point to be observed in regard to setting the tool is its height relative to the lathe centers. Fig. 88 illustrates this. Tool No. 1 is set below the center, and the dotted line, drawn tangent to the point of the tool

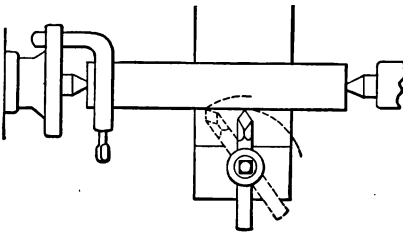


FIG. 87.

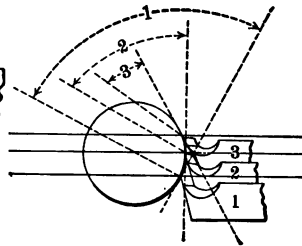


FIG. 88.—Setting Lathe Tool to Correct Height.

on the periphery of the circle, indicates the direction in which the cutting force is applied. The top or cutting surface of the tool forms an angle of 90° with this line. The stock is thus merely crowded off by the tool and there is no cutting or wedge action whatever. The next tool is set on the center and has more of a wedge action, but still not what it should have. The top tool, No. 3, gives us the best cutting edge and will do maximum work with minimum resistance.

From the foregoing it is clear that the lathe tool will do the best work with combination of top and side rake, when caught very short at right angles to the work, and when set above the center. This will lead to economy.

Now, a point about grinding: The diamond-point tool

should be ground only on the top, and the angles on the sides should never be touched, and there will be no danger then that you will destroy the economic value of the tool. Many mechanics burn the cutting edges of the tool in grinding by simple carelessness, which makes the edge softer than the metal it is supposed to cut. My references thus far have been confined entirely to the solid tools most commonly used. But there are many improved

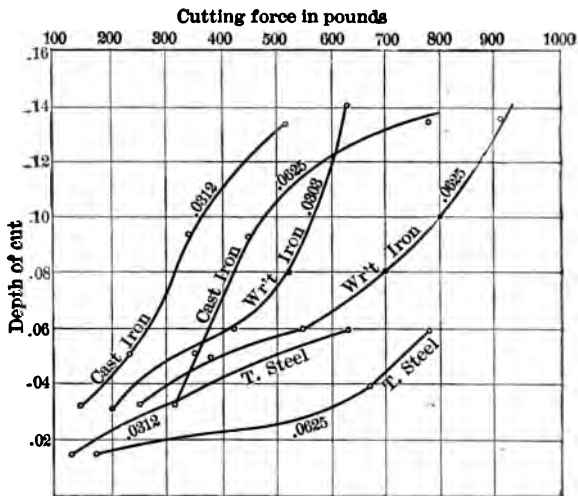


FIG. 89.—Chart Showing Cutting Force.

tool-holders in use designed for self-hardening steel, which is not affected by burning in the hands of incompetent mechanics, either in grinding or through lack of knowledge of the proper cutting speeds. These holders support the steel in such a position as to give the proper front and side clearance, and the rake is determined by the grinding.

Following is a table of finishing speeds and speeds for different metals for tools of ordinary tool steel. In roughing the axiom is slow speed and quick feed; finishing, high speed and fine feed. From this table I should deduct

25 per cent for roughing speed, making 18, 24, 28, and 83. Experiments on cutting tools made in the shops of R. H. Smith, London, England, and verified by the author, show that machine steel requires from two to two and one-half times the power for cutting as does cast iron, and wrought iron about one and one-half the power. The results are given in detail in the chart Fig. 89, herewith, and show that an increased force is required for increased cutting speed.

LATHE CUTTING SPEEDS AND FEEDS

FOR CARBON STEEL TOOLS

Tool Steel	Wrought Iron Machine Steel	Cast Iron	Brass
$S: F$	$S: F$	$S: F$	$S: F$
28: 25	40: 20	48: 16	120: 20
Lubricated	Lubricated	Dry	Dry

F = number of revolutions to 1 inch of feed.

S = number of feet per minute.

HIGH-SPEED TOOLS

Tool Steel	Wrought Iron Machine Steel	Cast Iron	Brass
$S: F$	$S: F$	$S: F$	$S: F$
38 to 45: 20	65 to 75: 12 to 20	60 to 70: 12	180 to 200: 20
Lubricated	Lubricated	Dry	Dry

Referring to Fig. 90 we will take up the rake and clearance of lathe diamond-point tools. The angle or clearance, sometimes called the angle of relief, as indicated here, is about 7° , sometimes running to 10° , more or less—enough

for a safe working angle. Really the only reason for so much clearance is to avoid rubbing against the cut surface, which would cause unnecessary frictional resistance to the motion of the lathe, and compel a change in the setting of the tool for every change of diameter. Our efforts should be directed toward finding the angle that will give the least force required for cutting, combined with endurance of tool edge.

While the power required to cut is increased greatly by dulness of the cutting edge, we must avoid the wood-chisel edge, because time lost for constantly removing the tool

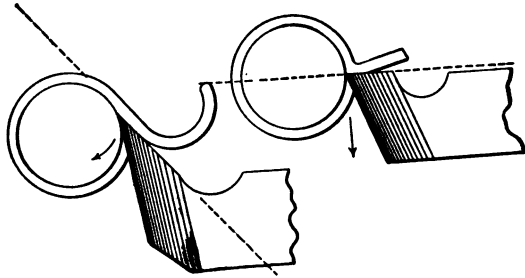


FIG. 90.

for grinding purposes eats up the profit. In Fig. 90 are illustrated two extreme cases—that on the left, having too great top rake, and the other having none. The one will do good work for a few minutes provided the cut is not too heavy, but the wear of the edge is so great that the angle would soon become blunt, and it would be very much better to have no top rake at all. On the other hand, the cutting edge, as I will call the tool ends on the right, is too blunt to do good, clean work, and from the position in which it is set, the chip will come off nearly straight and in small pieces. The happy medium between the two is found in Fig. 91.

Side rake means the angle at which the top is ground either to the right or left side. A tool ground for a tra-

versing motion toward the left hand cannot be used with a motion toward the right. Therefore side rake is designated right-hand or left-hand, the former meaning that it has its cutting edge on the right side and the latter on the left

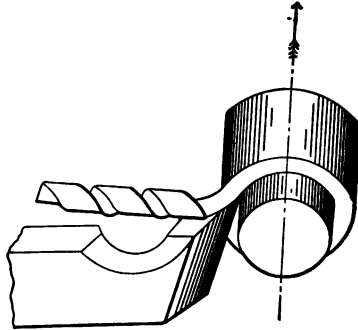


FIG. 91.

side. As the side rake is increased, the power to drive it on its traversing direction becomes less as it tends to screw its way along.

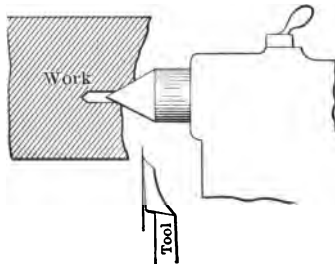


FIG. 92.

The round-nose tool, Fig. 82, is used for brass when made rather pointed, and for facing cast iron when it has a blunt point. The tendency with brass, which is very soft, would be to pull a hooked tool into the work. The side tool should always be set with the point leading slightly,

but one must remember that it is not the point, but the sides of the tool that is to do the cutting. This tool should be set on the center, as indicated in Fig. 93. Fig. 92 shows the necessity for facing up the work with the side tool before turning; otherwise the center will give more support to one side of the work than the other, and the pressure of the tool used later for turning will be likely to produce a crushing of the metal at the center, on the side of the least support.

The centering tool should be ground like a twist drill and placed with its cutting point directly at the center of

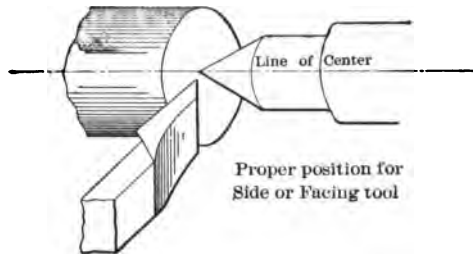


FIG. 93.

the work and used to obtain an accurate center for starting a drill. Much carelessness is exhibited in the use of the thread-cutting tool, not so much in grinding as in setting. It should be set so that the cutting edges are directly on the line of lathe centers and, of course, at right angles to it. The economical way to use this tool is to rough out the thread with a heavy cut and then regrind the top face until again sharp and then finish with a light cut. No matter how carefully a thread tool is used, the point will wear rapidly.

Referring to Fig. 94, we come to the cutting-off tool, the last of the lathe tools shown in Fig. 82. The upper view shows the action of the tool, and the two lower views indicate how good and poor results may be obtained through

grinding. This tool has side clearance right and left, and should be ground slightly concave on its top face. Its point should be on a level with the center of the work.

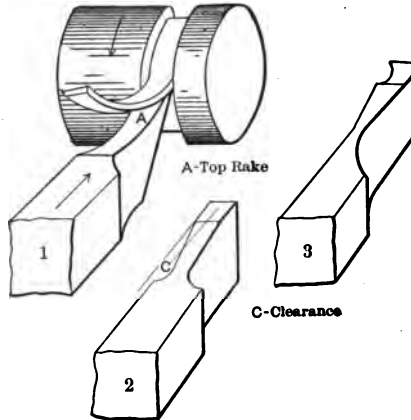


FIG. 91.

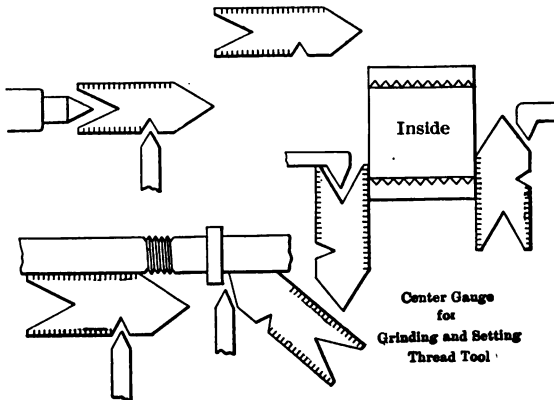


FIG. 95.

Fig. 96 shows a number of types of patent tool holders which are common in the modern shop because they are more economical for use on ordinary sizes of work. For

very large work, however, the *solid* tool is more economical on account of its rigidity, which is not always obtained in the built-up holder.

Competition has forced the use of any appliance whereby a saving may be made, and in the case of the tool holders

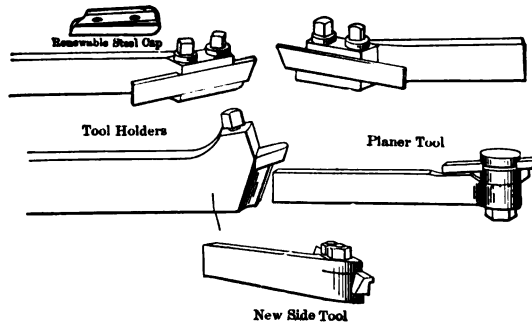


FIG. 96.

the amount of money tied up in tool steel is reduced to a minimum, which is not the case when solid tools are used.

The saving is made in two ways—the cutting edges do not have to be forged or redressed by the smith, and a more uniform angle of rake is maintained.

CHAPTER X

CUTTING TOOLS—(Continued)

Boring tools. Different kinds of boring tools. Difference between turning- and boring-tool rake and angles, and why. Different methods of holding work. Appliances. Cantilever principle defined in boring tool. Improved types of holders and their economic value.

Principle and Proper Angles. In Fig. 97 are indicated several of the more common types of boring tools. The vertical pressure on boring tools is very nearly constant (Fig. 98), and when the tool starts to cut, the depression

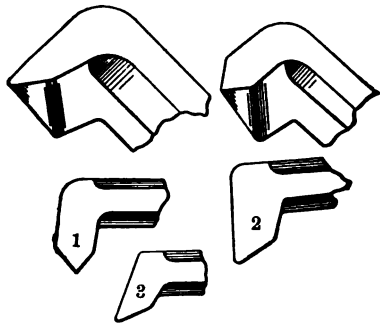


FIG. 97.—Types of Boring Tools.

or spring downward remains very nearly constant throughout its entire cut, and so does not vitally affect the accuracy. The tool wears as it advances, however, and this tends to produce a conical hole. While lathes are adjusted so that in no case they will bore a hole larger at the back

than at the front, in making this adjustment, however, the tendency is to have the lathe so it will bore very slightly smaller at the back—another reason why bored holes are frequently a little tapering. Do not decide, however, that it is the fault of the lathe—that it does not bore a hole straight; look to see whether the lathe is properly leveled up and that the four legs or bed are properly bedded. Very often we blame the builders for their poor work, when it is nearly always our own fault in not making conditions right. If the legs are not properly set there will be a wind in the shears of the lathe which will defeat good turning or boring.

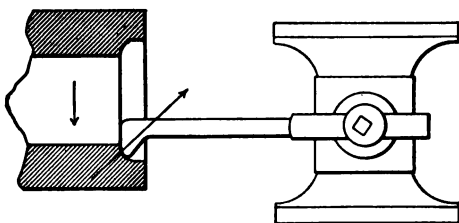


FIG. 98.—Cutting Action of Boring Tools.

The previous chapter is confined entirely to one class, namely, planer and lathe tools, and the different conditions under which the best results can be obtained from them. By best results I mean the maximum amount of good work with the minimum amount of energy expended—the ideal for which every good mechanic is striving. I tried to make plain the cardinal points for securing these results, such as proper top- and side-rake clearance, rigid setting, tool location so that it will not spring into the work, proper relation of cutting wedge to plane of work, etc. All these combine to make the cutting edge the basis of economic production, and economic production means not only least cost in manufacture, but a saving in wear and life of the machine.

I have purposely divided the subject of cutting tools into two separate heads, as there is a recognized distinction between inside and outside turning. The rake and clearance of a tool for inside turning must be different from that used for outside turning, for two reasons: First, because of the contracted and peculiar conditions under which the boring tool works, and second because of the spring of both tool and work—very serious conditions met with in boring which do not apply in outside turning. The spring of the work is overcome in many cases by

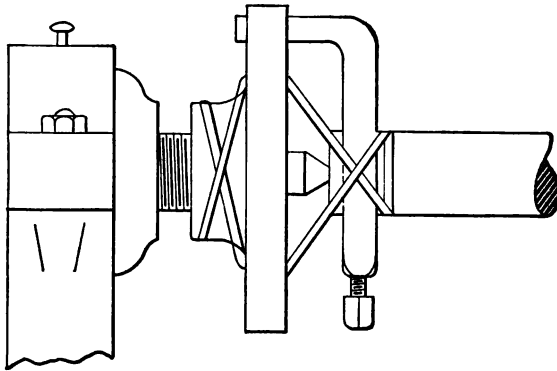


FIG. 99.

using a steady rest to support one end of the work while the other end is held in the chuck, or else is clamped to the face-plate, and in addition is sometimes supported by the live center itself.

In the latter case it must be laced to the face-plate.

Fig. 99 may serve as a help to some who have found difficulty in keeping the work tight against the center. It shows the face-plate partly unscrewed. The lacing is made fast to a dog or carrier in that position, and the face-plate is then screwed up in place, thereby tightening the thong. Now, unless great care and skill are combined in setting the steady rest in position, the result will be a

failure because, in boring, the object is to get the bore concentric with the outside, and it is a very easy matter to defeat this object by careless setting of the rest. A suggestion as to the way of setting may here be in order. If it is a piece that has already been turned on the outside the centers may be used to good purpose. Keep the live center in the lathe spindle, screw the chuck in position and put the work on centers as for ordinary turning. Now bring the chuck jaws down to the work and place the rest in position at the dead center end, the work all the while being still on centers. The rest is then opened, the chuck with the work in it unscrewed, and the center removed. This method will insure accuracy where it can be used.

If it is a rough piece of work that is to be set, support one end by the dead center, turn a true surface for the jaws of the steady rest, and place the same in position while the work is still on the center.

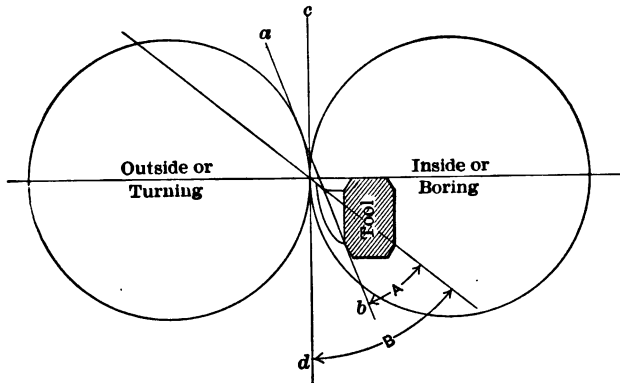


FIG. 100.

Fig. 100 will, I think, prove that the same laws do not hold for both inside and outside turning. The circle on the left represents a cylinder to be turned; that on the right, a hole to be bored, with the tool in position. The lines *ab* and *cd* are drawn tangent with the work at the

point where the cutting edge is in contact with the work when turning and boring respectively. On the face of it, it would seem that one vertical line should answer for both conditions, but not so, for in turning, we are enabled to set the cutting edge of the tool above the center of the work, hence changing the position of the lines and getting a finer cutting wedge. The angle A is the angle of the cutting wedge in turning, while B is the angle of the cutting wedge in boring. This is the best condition obtainable in boring, but it is not as good as can be desired.

Fig. 101 shows an old-fashioned boring tool of the type common in every shop. These tools are forged by the

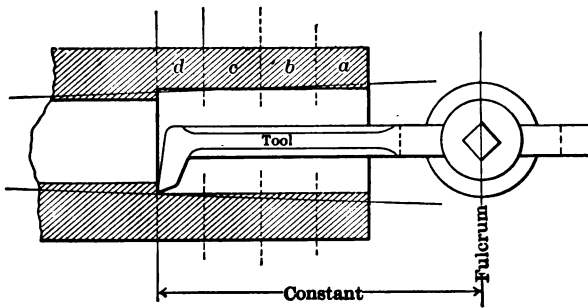


FIG. 101.

tool dresser in lengths and sizes that will cover a wide range of work, so that different diameters and depths may be bored without redressing. As to results from this type of tool: When the tool starts to perform its function—takes up its cut—there is a downward spring which we call vertical deflection, due to the pressure of the chip on the top of the tool. This pressure is nearly constant throughout the entire length of the cut, and does not vitally affect the accuracy of the work, particularly since there can be a slight vertical movement of the tool without appreciably changing the diameter of the surface being bored. This is not the case, however, with the

lateral pressure on the boring tool, which pressure, being at right angles to the cutting edge, deflects the tool away from the work more and more as the cutting edge dulls, thereby changing the angle of motion of the tool constantly. The result is a conical hole, and much time is lost in taking repeated cuts to get the bore parallel. This type of tool, therefore, does not prove economical, although the outward or lateral pressure will vary somewhat with the shape of the tool and the way in which it is dressed.

If the front or cutting edge makes an acute angle with the work, the lateral pressure is considerable; but if the cutting edge is at right angles to the work there is less tendency to deflect the tool in a sidewise direction. In the latter case, however, as the cutting edge wears away and the tool becomes dull, there is a tendency for the corner to become worn so as to form an acute angle and we will have some of the same trouble to contend with. Theoretically and practically, a tool ground as in Fig. 3 will give the best results, so far as cutting is concerned, but even by using the greatest care and judgment in dressing and grinding the tool, to reduce sidewise deflection, we cannot altogether remove the difficulty. The question of deflection is largely one of leverage. The amount of deflection will depend upon the length of the tool from the binding screw in the tool-post to the cutting edge.

After a tool is once made, its leverage is always a constant quantity, as indicated in Fig. 101, since the tool must always be placed in approximately the same position in the tool-post. It will therefore deflect as much in boring a short hole as in boring a long one, assuming the cutting edge to be in the same condition in each case. The longer the tool, the greater the deflection, for the tool is a cantilever the deflection of which is increased eight times when its length is doubled. From this, we can readily see how important is this consideration of leverage, and how desirable it is to have the boring tool adjustable, so that it need

project from the point of support only as far as is necessary to bore the full depth of the hole required. The mechanic should try to overcome this difficulty by devising ways and means for making the tool adjustable. Many schemes are open to the thinking mechanic.

Fig. 103 will give an idea for a tool holder and for different tools which are inexpensive and at the same time meet the above requirement. The holder gives at all

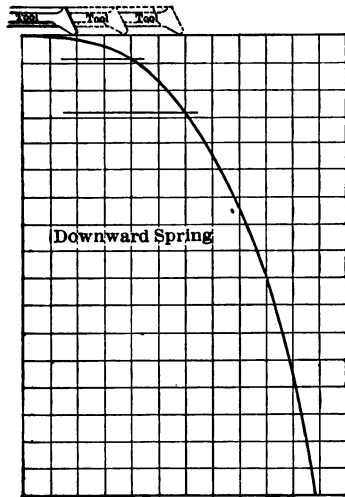


FIG. 102.—Shows Cantilever Curve.

times the greatest rigidity and allows the use of the largest size of tool possible for any particular work. It also enables the operator to vary the leverage to suit each particular hole.

The holder consists of a rectangular block of cast iron in which two holes are bored, one on each side of the center, and on a plane with the lathe center, and extremely close to the edges. After this, it is sawed in two through the center of the holes, the top forming the cap. The hole

may be made any standard size: $1\frac{1}{4}$, $1\frac{3}{8}$, $1\frac{1}{2}$. Into these holes are fitted sleeves, or the drill rod itself, although the sleeves give wider range of size of boring tool for each holder, by having a number of sleeves with different standard size holes. The tool fits in either *A* or *B* of the sleeves. If the tool is to be used in *A*, a solid piece is inserted in *B*, so as to give a support against which to cap the clamp. One end of the sleeve is knurled to allow the thumb and

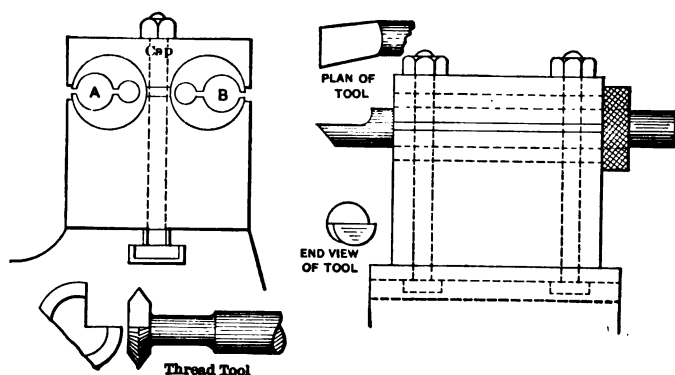


FIG. 103.—Boring Tool Holder and Type of Inside Threading Tool.

finger adjustment in raising and lowering the tool. Ordinary drill rod is used, filed down to a flat surface at the end as shown. When heating for the tempering process, set over the filed end by a blow of a hammer for clearance. A tool nearly the size of a hole to be bored may be used, for instance, and a thread tool of this type may be used to bore a $\frac{3}{4}$ hole, and is of the greatest advantage in that the tool is always level, the requisite for a true-angle thread.

QUESTIONS ON CUTTING TOOLS

Give table of United States Standard threads.

Give formula for diameter at bottom of thread, of United States Standard and V-threads.

What is the difference between pitch and lead of a thread?

What proportion of the lead is the pitch on a single thread?

On a double thread?

Why do you use a lubricant on a fibrous material?

What is a good mixture for this?

How large is the flat (in terms of pitch) at top and bottom of United States Standard thread?

What combination of feed and speed is satisfactory for roughing cuts, in general?

What is the meaning of cutting speed?

A piece of stock is 12" long, and is to be tapered $\frac{1}{4}$ " per foot. How much must the poppet head be set over? Give calculation in note book.

What is the best method of finishing work in the modern shop?

What sort of a gauge is commonly used for sizing when taking a finishing cut? Describe it.

How is a turning tool ground for finishing?

What is the correct angle between the faces of the diamond point?

Make sketch of a tool without either side or back rake and explain its action.

Is such a tool correctly ground?

What class of tools do you study first?

Should a planer tool have much clearance?

State the smallest amount permissible.

Should there be a great amount of top rake on a planer tool?

Are you permitted to give considerable side rake?

Make sketches showing the various tools used on the lathe.

State a law covering the loss of power due to grinding the cutting face of a tool, so it is parallel with the axis of the work.

If you turn a piece of rough work, will it show any of the irregularities of the rough surface in the finished piece?

Why will a piece of work be out of round after turning, if it is not centered true?

State a second reason why a planer tool is apt to bite into the work, and explain its action in so doing.

What may cause a "chattered" surface, on planed work, besides springing of tool?

Which is the better for producing smooth work on a surface, the rack and gear, or the worm-drive planer?

Give a sketch showing how a planer tool may be designed to avoid "biting" into work.

Give a sketch showing the ideal form of finishing tool.

What is the proper angle of clearance in the lathe tool?

What is the reason for a large clearance on the lathe tool?

Toward what should our effort be directed on selecting the angles of cutting tools?

Is top rake necessary on a good cutting tool?

Is the wood-chisel edge a satisfactory form of tool? Why?

What is side rake?

How is it designated?

Describe the two side rakes.

Give a sketch and explain effect of setting tool above and below center of lathe.

Give a full description of the proper setting of a tool in the lathe.

Should a forged diamond point be ground on the sides?

Give a table of cutting feeds and speeds for various metals.

What sort of a tool is used for brass work?

What is the tendency of a hooked tool when used on brass?

How should a side tool be set?

How should it be set relative to the center?

How should a centering tool be ground?

How should a thread tool be set?

What is the economical method of using a thread tool?

How should a cutting-off tool be ground?

How is the spring of work overcome in a great deal of boring work?

Make sketch and give description of method of lacing a piece of work against the live center in back-resting.

Give description of method of setting a finished piece in the back-rest for boring.

Give a description of the proper method of setting a rough piece in the back-rest.

Make a sketch of a correctly ground boring tool.

Suppose we have two boring tools, one 4" from tool post to cutting point, and another 8" from tool post to cutting point. How much more will the longer one be depressed by the same cut than the shorter one?

Make a sketch and give a careful description of the boring-tool holder shown on page 4, of boring tools. Describe method of making boring tools for this holder.

Make a sketch and give a description of a boring bar.

What should be the angle of the lips of a drill with the longitudinal axis for cutting iron and steel? For brass?

What is a sure indication of the lip clearance on a drill? Give sketches illustrating this clearance, as well as description.

What is the effect of too much clearance?

Give sketches showing result of improper grinding of drill. Explain them.

What is the result of using a drill with a thick point?

If a drill runs out of center in starting a hole, how may it be drawn into center again?

How should you start a drill where very accurate work is required?

Give a sketch of a "farmer" drill, and tell on what class of work it is used.

Give a table of feeds and speeds of the various size drills.

Give sketches and description of method of drilling very deep holes of small diameter. How is the boring bar constructed? How is the work fed to the boring tool? For what are the steady rests used? How is the cut started?

CHAPTER XI

BORING MILLS

VERTICAL AND HORIZONTAL

Their functions as productive machines. Construction of table.

Difference between the two types of machines. Facing attachment. Boring bars. Tools.

THIS is ostensibly a face plate lathe inverted.

The life and accuracy of a lathe depends largely upon its main spindle, and unless the head stock is made very large the size of the spindle must of necessity be limited in size. In clamping work on the face plate of a lathe for purposes of boring, we know that as the size and weight of the work increases, the difficulty of setting and securing in place becomes more involved, but aside from this we have the weight of the enormous overhanging parts, which increases the friction on the journal bearings, creating rapid wear; we have also to contend with increased vibration as the weight increases.

In the construction of the vertical boring mill this has all been eliminated; increased size of bearing is possible and so designed that the table has self-centering tendency, a very important consideration.

The work is easily clamped or chucked in position with less loss of time, and the multiple-head construction makes it possible to still further cheapen production by having a number of tools operating at the same time.

Fig. 105 shows the large angular-bearing construction of the table, with method of oiling and driving, etc.

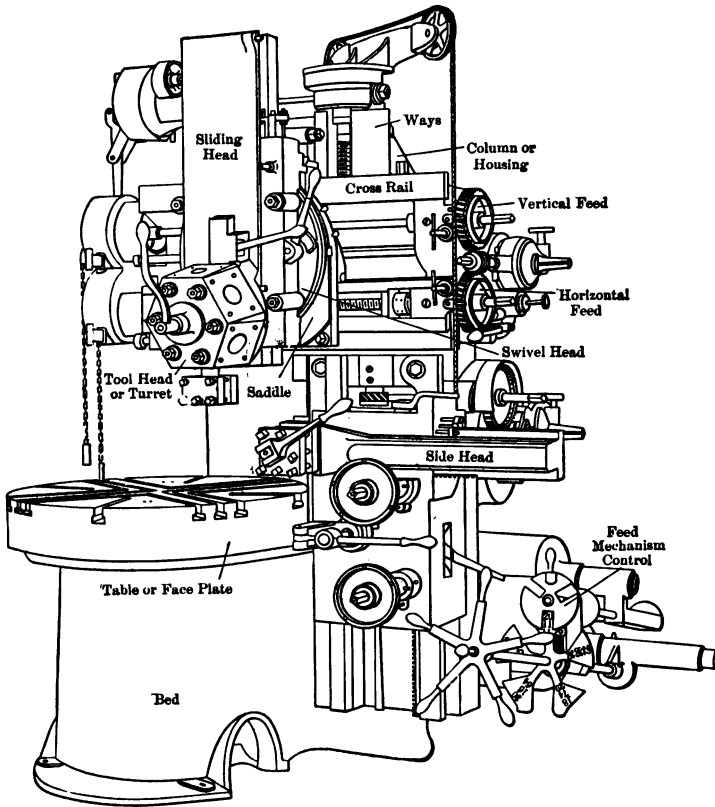


FIG. 104.—Bullard Vertical.

	Liner for wear (Babbitt or bronze)	Table (C. I.)	Work			
Bed (C. I.)	Column or Housings (C. I.)	Ways (C. I.)	Cross rail (C. I.)	Saddle (C. I.)	Sliding head (C. I.)	Turret or tool head (C. I.) Tools
		Side head (C. I.)	Tool box (Cru. steel)	Tool (T. S.)	Swivel head (C. I.)	
		Feed mechanism and control, (C. I. and steel)				

These machines are designated by the size of the table, as for instance a 30-inch mill has a table 30" in diameter. The smaller mills are made with single housing which carries the cross rail; the sizes above 36" are made with double housing similar to that of a planer, and connected with a top rail as indicated in chart. These machines carry multiple tool head or turret capable of holding a complete set of tools for finishing a job.

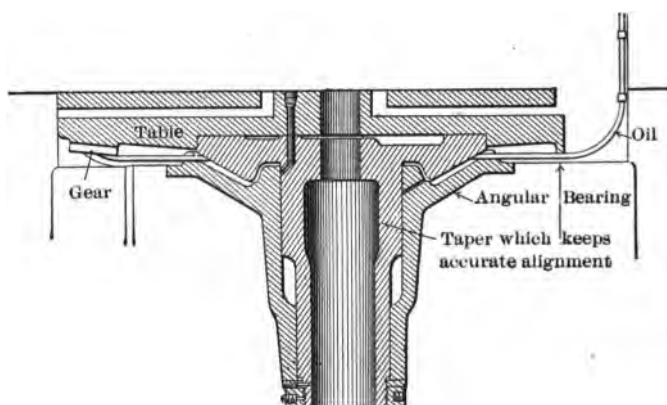


FIG. 105.

Vertical boring mill and the relation of the parts to each other.

Bed	Housings	Slide tool head	Turret tools
		Cross rail	Tool head
	Table	Top rail	Feed and mechanism
		Driving gear	
		Cone pulley-driving mechanism	

As a manufacturing machine it is ranked among the foremost. It is more easily adaptable to jigs and fixtures than the old type face plate lathe, and can be run at higher rate of speed and heavier feeds, due to its perfect balance of rotating parts.

In the vertical type of machine the work moves, and the tool is fed against it.

In the horizontal type the work is stationary and the

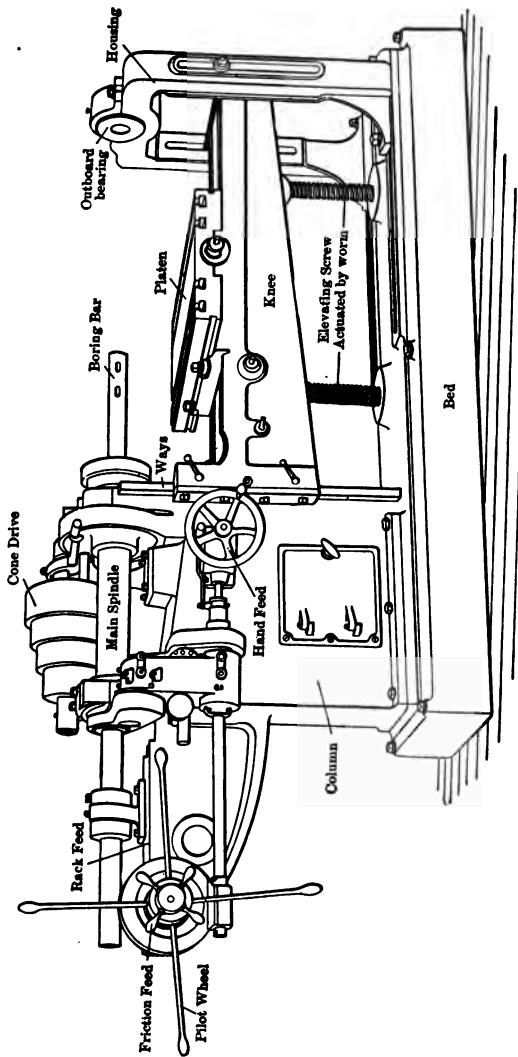


FIG. 106.—Binsse Horizontal Boring Machine.

Bed (C. I.)	Feed mechanism (Cru. steel)		
	Ways	Knee	Platen
Column (C. I.)	Work		
	Main spindle	Boring bar	(Cru. steel)
Housing (C. I.)	Bushing		
	Cone pulley transmission		
	Outboard bearing		
	Boring bar		

tool, which is carried by either the main spindle or boring bar, or by tool head clamped to the bar, has both rotation and feed.

The horizontal boring machine is built on two distinct principles of construction or machine design. In one, the bar, which is carried in a sliding head on an upright housing, as in Fig. 107, is raised or lowered to suit work conditions. In the other, the work is raised or lowered to suit bar conditions, as in Fig. 106.

The important thing is to maintain parallelism, and when the table moves, as in Fig. 106 by means of screws *yy*, unless the table is gibbed light and at right angles to start, the tendency to shift the level of the table each time it is moved is inherent. On the other hand, any change in the outboard bearing bushing, wherein it does not move accurately with the bar movement, is open to the same criticisms.

Both types of machine have a broad field of usefulness and are classed as cheap-production machines, because of their adaptability to jig and fixture design. Special forms of horizontal boring machines are in use for specialized product, such as frames for railway motors, cylinders for locomotives, etc. Where the bars and both faces of the cylinder can be machined at the same time by means of the facing head attachment, as illustrated in Fig. 108, a device for clamping on the main bar or face plate of machine performs the same function as the slide rest on a lathe when the tool post moves along ways.

The tool post traverses the entire length of the ways by means of the screw *A*, and these ways, being at right angles to the plane of the bar, face the cylinder head.

The feed is the primitive star wheel feed, which is at least fifty years old, this same feed being used on the old-type lathes that did not have power-feed attachments. The principle of its operation is rather ingenious, as the amount of feed can be varied at the will of the operator.

As the head *X* is rotated by the bar the star wheel

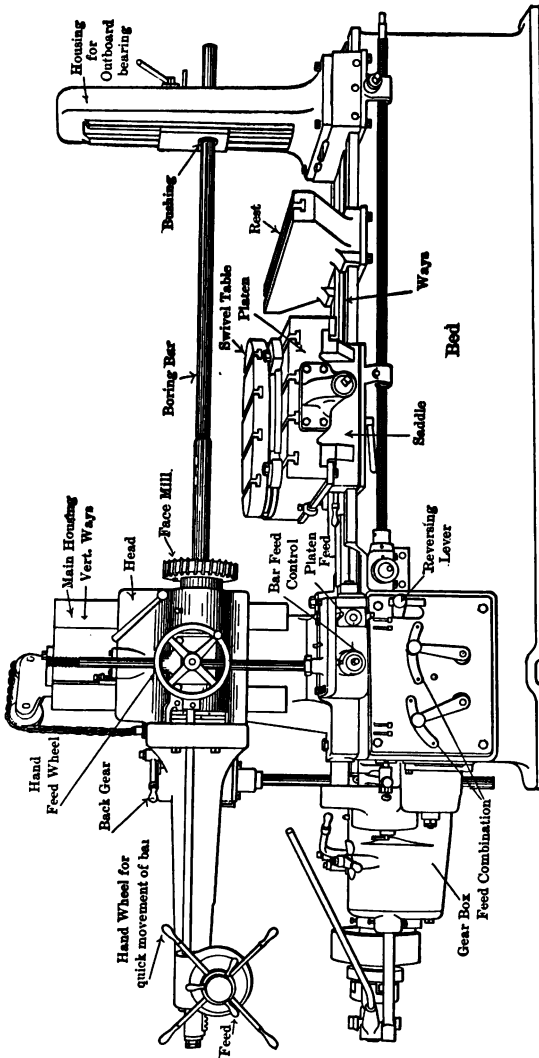


FIG. 107.—Lucas Boring Machine (Cleveland).

Column (C. I.)	Head (C. I.)	Spindle bearing (C. I.)	Main spindle (Cru. steel)	Boring bar (Cru. steel) or cutter (F. S.)
Ways (C. I.)	Housing (C. I.)	Saddle (C. I.)	Platen (C. I.)	Back and pinion (C. I.)
Bed (C. I.)	Bushings for outboard bearing (C. I.)	Transmission mechanism (C. I. and steel)	Feed (Cru. steel)	Work (C. I.)

comes in contact with a stop pin which is clamped on the bed of the machine, or fits in hole designed to carry it; one of the points of the wheel strikes on this pin, which

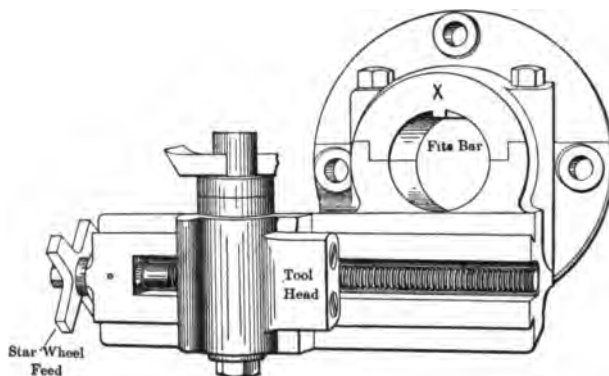


FIG. 108.

necessarily rotates the star wheel, which in turn rotates the screw which actuates the tool.

CHAPTER XII

MILLING MACHINES

How classified. Value of multiple-tooth over the single-tooth cutter.

Little things that will defeat accurate work. The arbor. Collets. Gang milling. Index head and its construction. Its use as a dividing factor. Calculations of index circles. Compound indexing. Spiral milling and calculation of gears. Angle of lathe for different pitches and how determined by mathematics. Graphic method. Table of natural tangents. Formed cutters. Setting of cutters. Chart for depth of cut. Speeds and feeds.

Difference between Plain and Universal Milling Machine

Construction. Milling machines are designated either as plain or universal milling machines, and if the average mechanic were asked to name the features which distinguished the two, it would perplex him, because it is true that the mechanic very rarely makes a study of his machine.

Fig. 109 illustrates the type of construction of a plain milling machine, and it will be seen that the platen cannot be changed from its right-angle position, hence is not available for spiral milling.

Fig. 111 illustrates the type of construction of a universal milling machine, with compound saddle, which enables the platen to be swung at any desired angle to give cutter clearance for spiral work. *The workman should know his machine if he would get its greatest efficiency.*

Of all machines in the modern plant, the milling machine, it is safe to say, is the least understood, hence its great efficiency as an economic producer is limited, and there

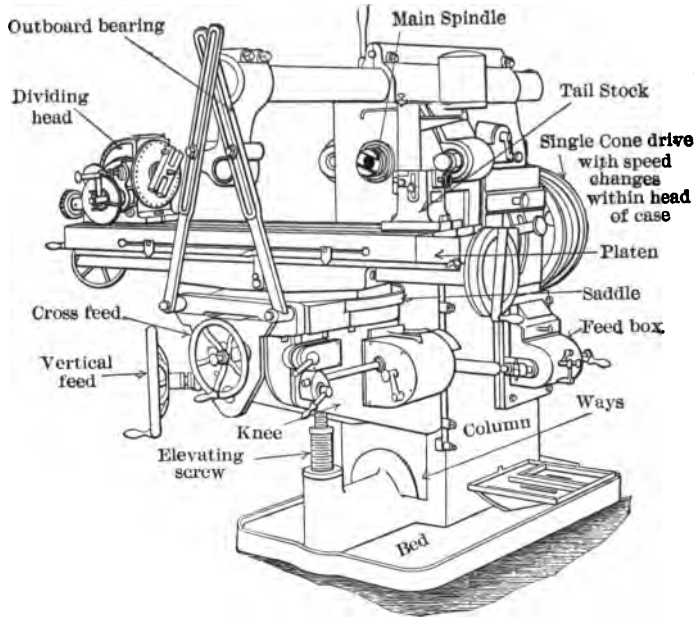


FIG. 109.

Milling machines and the relation of parts to each other.

Base	Column	Knee	Saddle	Platen	Dividing head
		Cone pulley	Support for outboard bearing		
		Back gears			
		Main spindle	Arbor	Cutter	Tail stock
		Feed mechanism		Collets	Nut

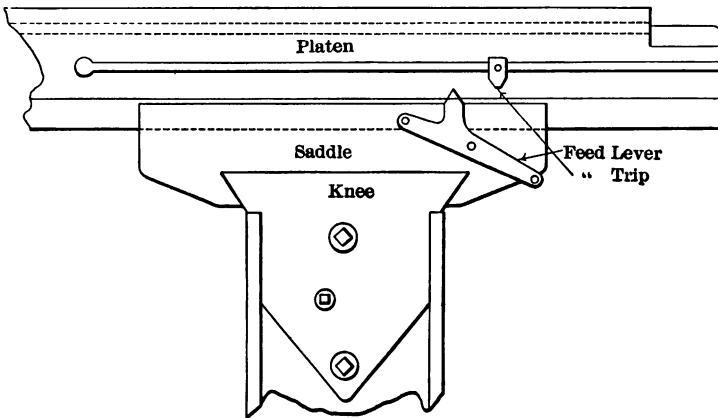


FIG. 110.—Construction of Plain Milling Machine.

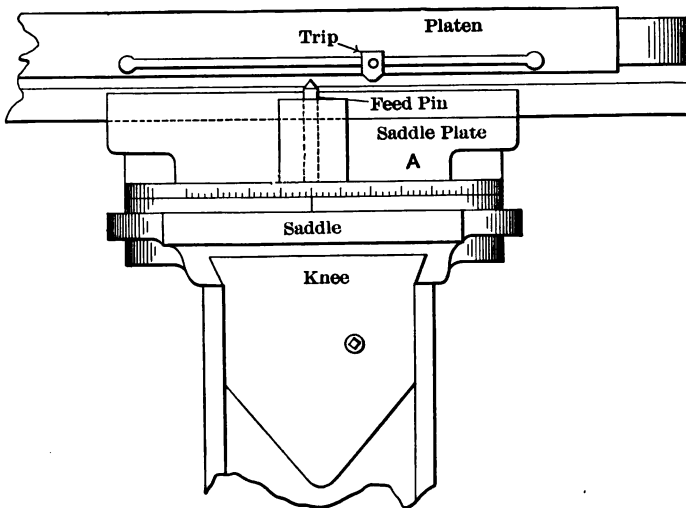


FIG. 111.—Construction of Universal Milling Machine. (Brown & Sharpe.)

is no machine that will give a greater return for a conscientious study of it than this one.

A thorough knowledge of it is a liberal education to any mechanic, and he who masters it will get more

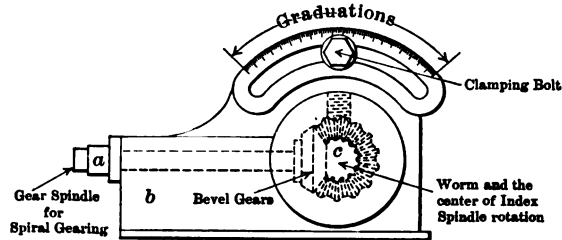


FIG. 112.

and better work out of any of the other machine tools. Mediocre results have been obtained by many operators of this machine, simply because of their failure to study

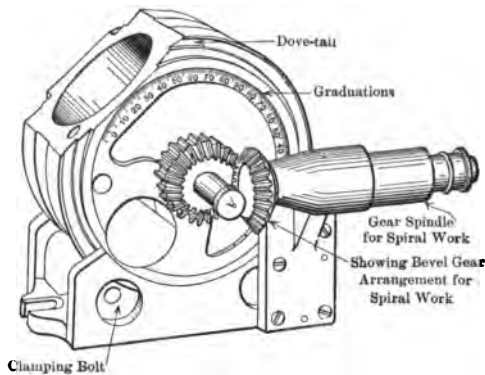


FIG. 113.

all the conditions of machine design, and use them for this end, and because, also, of their lack of care and observation in the little things which go to make up the perfect whole.

It is by far the most useful machine in the modern

equipment, and it is available for the greater part of the work that was formerly and is to-day, in many shops, done on the shaper and planer, and is a more economical producer.

The advantage of the multiple-tooth cutter over the single cutter must be apparent to every mechanic; longer life and the economy of time are the chief factors, but to get those advantages, certain fundamental principles of the machine construction must be understood by the operator. He must know the why of all the little details.

The first important thing to study is the arbor, which carries the milling cutter.

It is supposed to fit into the taper which is bored in the front end of the main spindle of the machine; before putting

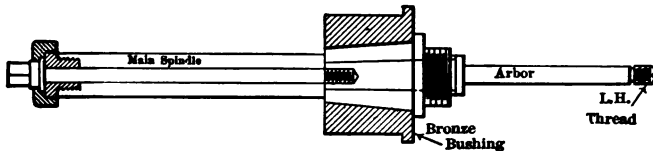


FIG. 114.

it in place see that the hole is perfectly clean and free from dirt of any kind, also that the taper on the arbor is thoroughly clean. There is no recognized standard tapers for these arbors, different makers having their own individual standards.

The arbor should fit perfectly in its socket, and should have a key also, not relying on the friction alone to drive and prevent slipping.

These arbors are drawn into place by a long rod which runs through the hollow spindle of the machine.

This rod has a collar, as in Fig. 114, which beds against a sleeve which screws into back end of main spindle, Fig. 115; this sleeve being thus constructed for the purpose of removing by screwing in against the collar *F*.

The arbor is ground to some standard size, according to

size of the machine it is intended for, $\frac{7}{8}$ or 1" diameter, and collets of varying lengths are made for the purpose of spacing cutters, also acting as washers for holding the cutter tight. The cutter also should be held by key to keep

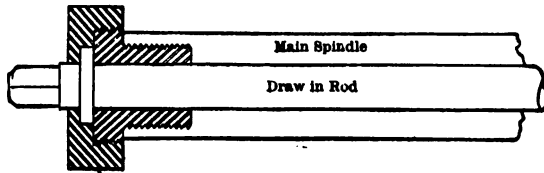
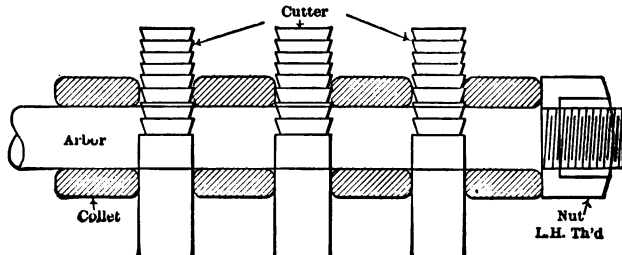


FIG. 115.

from rotating and not rely on the frictional hold of the collets.

The varying lengths are for the purpose of gang milling to space the cutter as in Fig. 116.



GANG MILLING

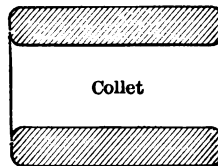


FIG. 116.

It is very important that these collets should be faced true and parallel, and at right angles to the plane of the bore, the edges being rounded as in Fig. 4, because the

rounded edges prevent any possibility of the faces becoming burred. This is very important, for these collets are among the most important attachments on the milling machine, for no matter how well designed or how powerful the machine may be, carelessness in this particular will surely defeat good work.

The question naturally arises, Why is so much emphasis laid on these collets? And it is now answered by the other question: What is the advantage of having a cutter with 32 teeth unless every one of the 32 teeth performs an equal part of the cutting work? This is only possible when the arbor runs perfectly true, and to insure this, the collets must be perfectly true, with no dirt or burr on their faces, for if there is, when the nut is tightened the arbor will bend with the result that it and the collet will run out of true, cutting only on the high side, and with but few teeth.

The arbor is also supported on the outer end by the outboard bearing which slides along the overhanging arm. The nut on the arbor has a left-handed thread in order that the cutting resistance may tighten rather than loosen it, which would be the case were it right handed. Fig. 116.

Other Parts of Milling Machine. The column is the main casting upon which the knee travels up and down. On this knee is supported the saddle, which gives the in- and out-feed movements; the saddle supports the platen, which gives the traversing feed, and on the platen rides the index head and tail spindle, both of which have centers upon which the work is supported. The difference between the plain milling machine and the universal is, that the saddle cannot be swiveled on the plain, and can be on the universal, hence on the plain milling machine no spiral work can be done.

On all the feeds or screws used to give motion to the work are discs graduated to read in thousandths of an inch, insuring great accuracy. The milling cutter should be

INDEX TABLE

Number of Divisions.	Number of Holes in Index Circle.	Number of Turns of Crank.	Number of Divisions.	Number of Holes in Index Circle.	Number of Turns of Crank.
2	any	20	35	49	$1\frac{7}{49}$
3	39	$13\frac{13}{39}$	36	27	$1\frac{3}{27}$
4	any	10	37	37	$1\frac{3}{37}$
5	any	8	38	19	$1\frac{1}{19}$
6	39	$6\frac{26}{39}$	39	39	$1\frac{1}{39}$
7	49	$5\frac{35}{49}$	40	any	1
8	any	5	41	41	$\frac{40}{41}$
9	27	$4\frac{12}{27}$	42	21	$\frac{20}{21}$
10	any	4	43	43	$\frac{40}{43}$
11	33	$3\frac{21}{33}$	44	33	$\frac{30}{33}$
12	39	$3\frac{13}{39}$	45	27	$\frac{24}{27}$
13	39	$3\frac{3}{39}$	46	23	$\frac{20}{23}$
14	49	$2\frac{42}{49}$	47	47	$\frac{40}{47}$
15	39	$2\frac{26}{39}$	48	18	$\frac{15}{18}$
16	20	$2\frac{10}{20}$	49	49	$\frac{40}{49}$
17	17	$2\frac{6}{17}$	50	20	$\frac{16}{20}$
18	27	$2\frac{6}{27}$	52	39	$\frac{30}{39}$
19	19	$2\frac{7}{19}$	54	27	$\frac{20}{27}$
20	any	2	55	33	$\frac{24}{33}$
21	21	$1\frac{19}{21}$	56	49	$\frac{35}{49}$
22	33	$1\frac{27}{33}$	58	29	$\frac{20}{29}$
23	23	$1\frac{17}{23}$	60	39	$\frac{28}{39}$
24	39	$1\frac{26}{39}$	62	31	$\frac{20}{31}$
25	20	$1\frac{12}{20}$	64	16	$\frac{10}{16}$
26	39	$1\frac{21}{39}$	65	39	$\frac{24}{39}$
27	27	$1\frac{18}{27}$	66	33	$\frac{20}{33}$
28	49	$1\frac{21}{49}$	68	17	$\frac{10}{17}$
29	29	$1\frac{11}{29}$	70	49	$\frac{28}{49}$
30	39	$1\frac{13}{39}$	72	27	$\frac{15}{27}$
31	31	$1\frac{9}{31}$	74	37	$\frac{20}{37}$
32	20	$1\frac{5}{20}$	75	15	$\frac{8}{15}$
33	33	$1\frac{7}{33}$	76	19	$\frac{10}{19}$
34	17	$1\frac{3}{17}$	78	39	$\frac{20}{39}$

located on the arbor as close to the cutter or main casting as the work will admit, so that as short a leverage as possible is secured, and the outer bearing brought also as close to the cutter as possible, and yet clear the work. The greatest care should be taken in the grinding or re-sharpening of the

cutter also, for if the teeth are not ground uniformly, the cutter will run out of true, and the same result effected as spoken of regarding the arbor.

The Index Head. In examining the construction of the index head, you will notice that the housing is graduated in degrees, which indicates at once that the head can be swiveled to any angle for taper work of any kind, bevel-gear clutch work, etc. The method of clamping in any desired position is by means of the bolts *a, a* on either side, which clamps it rigidly in any desired position.

After using it in any desired position out of the horizontal or level one, it is not wise to rely on the graduations to bring it back into place, for it is difficult to set by eye any two lines, such setting being at all times only an approximation; nor can it be set by pushing the tail spindle up to it and again relying on the eye. A straight cylinder—either cast iron or any other material—should be put on centers, and by bringing the mandrel or cylinder up toward the cutter and feeling contact with a piece of heavy paper such as an ordinary envelope, about .004 thick, then reversing the mandrel or cylinder and repeating the operation of calibrating with the paper, great accuracy can be obtained.

The mechanism of the index head is so arranged through the medium of the worm and worm-wheel that the index head spindle can be rotated, and with it the work which is carried out with it, so that any part of the working surface, square or round, can be operated upon.

There is a definite ratio between the worm and worm wheel of 40 to 1, that is, 40 turns of the crank, which operates the worm, will rotate the worm wheel, which is fastened to and travels with the spindle of the head.

After one side is cut, run the work away from the cutter far enough to insure clearance in turning the work. Then pull the crank toward you out of the hole, and be careful not to move the position of the fingers, and do not turn

the handle beyond the stopping point, because in running any lost motion in the head will defeat accurate dividing. Always stop between the last two holes and gently push to the required stop hole; the pin will then spring into place and hold it as indicated in Fig. 117.

We have thus far only described what is known as direct indexing, and while the description covers most of the work of the index head, there are times when it may be necessary to compound the indexing, in case it is desired to make divisions, when no circle in the index plate will cover.

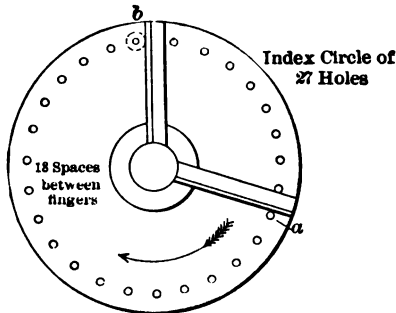


FIG. 117.—Six Turns past *a* and up to *b*, 18 more holes.

Brown & Sharpe, in their treatise on the index head, use, as an example, 69 divisions, and very clearly illustrate the method of obtaining them, through compound indexing.

In dividing the work into 69 parts, they use the 23 circle on the index plate, and the 33 circle.

21 holes on 23 circle and 11 holes on 33 circle.

If the head were moved 21 holes it would give $21/23$ of a turn, which is too far. $21/23 = 63/69$, and we desire only $40/69$ for each division, hence it has moved $23/69$ too far. The 11 holes of the 33 circle represent the deduction, or backward movement, as

$$11/33 = 1/3 \quad \text{and} \quad 23/69 = 1/3,$$

hence

$$(21/23 - 11/33) = (63/69 - 1/3) \text{ or } = 40/69.$$

The method is as follows:

The work is turned through 21 spaces or holes in the 23 circle, and then turned in the opposite direction 11 holes on the 33 circle.

The first movement is made in the ordinary direct indexing manner. The stop pin, which keeps the index plates from rotating when the crank is being moved, is placed in the 33 circle, the crank is pulled out and moved 21 spaces on the 23 circle, numbering them off by means of the fingers. The next movement leaves the index crank in the 23-hole circle, and the stop pin is pushed out of the 33 circle, and the whole index plate moved 11 holes in the opposite direction from that made by the crank. These holes must be counted, and the mistake of counting the stop pin hole as one of the 11 avoided. Count 11 beyond the one in which the stop pin was. It is important in all indexing to remember that the number of holes is always independent of the one in which the pin is at the time.

Milling Spirals. The difference between the plain milling machine and the universal has already been noted, and on the universal milling machine only can spiral work be done, owing to the construction which enables the platen to be swung at any desired angle to accommodate itself to the pitch desired. The movement of the platen to any angle has no function other than for clearance of milling cutter, so that the cutter can produce its shape, and has no connection whatever with changing the pitch as the angle of the platen is changed. This desired pitch can be obtained if the lathe is left in a plane, only the shape of the cut would change. Get this firmly fixed in mind.

In speaking of the pitch of a spiral is meant the distance the lathe (which of course carries the work) would travel while the work was rotated once.

Note the construction of the indexing head and see how this compound motion is effected. The small spindle *a*, Fig. 112, extends through box *b* and carries a bevel gear which engages with another bevel gear which is keyed on the shaft, which carries the worm *c*. On the opposite end of this same shaft is an extension or bearing upon which spin gears of various sizes can be slipped. The gear for this worm is engaged by means of a yoke which carries two gears, which, in turn, engages with the gear on screw.

Four gears then are necessary for spiral work, namely, gear on worm, first gear on yoke stud, second gear on yoke stud, and gear on screw which operates platen movement, Figs. 118, 119.

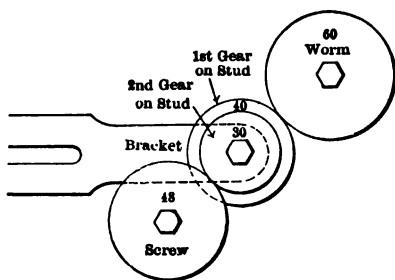


FIG. 118.

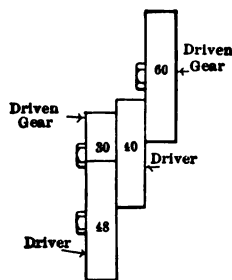


FIG. 119.

Fig. 118 shows arrangements of gears for spiral cutting, and indicates first gear on stud (the first gear slipped on) and the second gear on stud as the one following it. This is Brown & Sharpe practice in disengaging the stud gears.

To obtain gears for any desired pitch or spiral, it is essential that the lead of the machine platen be known. As indicated in Fig. 118, the gear on screw and the first gear on stud are the driving gears, the second gear on stud and the worm gears being driven. Now if the number of threads per inch on the screw were 4, and knowing that the ratio between the worm and worm wheel is 40 to 1, it is obvious that if gears of equal size were connected

together the lathe would advance 10" while the index head revolved once.

If 5 threads per inch was the lead screw, with the same equal size gears the advance of lathe would be 8". Hence we designate this as the lead of the machine. Now the driven gears are certainly actuated by the driving gears, and it is also true that the length of spiral desired is in ratio to the lead of the machine, hence the

$$\frac{\text{Driven gears}}{\text{Driving gears}} = \frac{\text{Required spiral}}{\text{Lead of Machine}}$$

The ratio of the driven gears to the driving gears is a fraction of the required spiral divided by the lead of the machine; as, for instance, it is desired to cut a spiral of 20" to one turn on a machine with a lead of 10" unit.

It can be expressed as $\frac{20}{10}$, but we need 4 gears to obtain this, so we will resolve this $\frac{20}{10}$ into factors of $\frac{4}{2} \times \frac{5}{5}$, which, multiplied together, gives $\frac{20}{10}$.

Now multiply both terms of the first fraction $\frac{4}{2}$ by some number, say 20, and we have $\frac{4}{2} \times \frac{20}{20} = \frac{80}{40}$. Do the same with the other fraction $\frac{5}{5}$, say 10, and we have $\frac{5}{5} \times \frac{10}{10} = \frac{50}{50}$. Now the $\frac{20}{10}$ is resolved into $\frac{80}{40} \times \frac{50}{50}$; the 80 and 50 are the driven gears; the 40 and 50 are the driving gears, so

80 on the worm gears,
50 the first gear on stud,
50 the second gear on stud,
40 on the screw,

would give a spiral of 20" to 1 turn, which can be readily seen, as the size of worm is double that of the screw gear, which would double the lead of 10", as both stud gears are equal.

To obtain a spiral cut it will be necessary now to swivel the lathe or platen a certain number of degrees for cutter clearance.

Taking the same 20" to 1 turn, assume that it is to be a twist drill of 1" diameter that we desire. There are two ways of getting this angle, one by laying it out on a sheet of tin or paper and using a bevel protractor, and the other by figures.

The graphical solution: We know that the length is to be 20"; draw a horizontal line 20" long, as in Fig. 120.

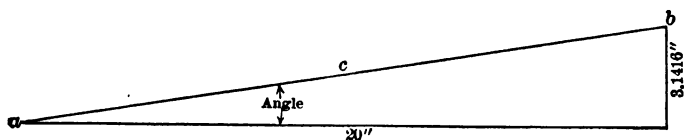


FIG. 120.—Scale One-quarter Size.

The diameter is 1", but we do know that the spiral traverses the whole circumference, which is 3.141 times the diameter. Draw a vertical line 3.141" at extreme right-hand end of the 20-inch horizontal line at right angles to it, and connect the two points *a* and *b* with a line *c* and with bevel protractor the angle of this line is obtained, and by cutting out of paper and winding it around the work, the angle is designated. The method of figuring the angle is quite simple when you interpret the mathematical terms of sine, cosine and tangent. The sine divided by the cosine will equal an equivalent angle root or tangent, and is expressed as follows:

$$\frac{\text{sine}}{\text{cosine}} = \text{tangent.}$$

Taking the same spiral of 20" the vertical line of 3.141 is the sine, and the horizontal line of 20" is the cosine.

$$\frac{\text{sine}}{\text{cosine}} = \frac{3.141}{20} = .1575 = \text{tangent.}$$

Looking on a table of natural tangents we find the figures .1575 not given, the nearest to it being 1583, which equals 9°, indicating that, as 1583, which equals 9°, is slightly more than .1575, the angle at which we must set the table is not quite 9°.

On pages 124–125 is a table of natural tangents for whole degrees, and the fractional degrees can be very readily figured between the two nearest numbers, one under and one over the amount.

Milling Cutters. The simplest form of milling cutter is commonly termed a fly cutter. A single cutting edge, formed to suit any desired shape, is cheaper than a regularly formed milling cutter, and is useful in model work, particularly when only one or two parts of a kind are required, and when expense is a factor. It is particularly adapted to production of irregular shapes and contours such as are required on screw machines. Having only single cutting edge, the wear is of course greater than in multiple tooth, hence it needs grinding more frequently.

The efficiency of the milling cutter depends upon the sharpness of the cutting edge. No multiple tooth cutter can be ground by hand.

All cutters are *form* cutters, in that they produce some form, but the term *formed cutter* is applied to the construction of the cutter from the standpoint of clearance, which is so designed that *size* of cut and *form* remain constant, no matter how often it is ground, as indicated in Fig. 122.

There is a limit to the size of these solid formed cutters, and the limit is controlled partly by the economic factor.

First, the amount of tool steel, which costs considerable.

NATURAL TANGENT

Deg.	0'	10'	20'	30'	40'	50'	60'	
0	.00000	.00290	.00581	.00872	.01163	.01454	.01745	89
1	.01745	.02036	.02327	.02618	.02909	.03200	.03492	88
2	.03492	.03783	.04074	.04366	.04657	.04949	.05240	87
3	.05240	.05532	.05824	.06116	.06408	.06700	.06992	86
4	.06992	.07285	.07577	.07870	.08162	.08455	.08748	85
5	.08748	.09042	.09335	.09628	.09922	.10216	.10510	84
6	.10510	.10804	.11099	.11393	.11688	.11983	.12278	83
7	.12278	.12573	.12869	.13165	.13461	.13757	.14054	82
8	.14054	.14350	.14647	.14945	.15242	.15540	.15838	81
9	.15838	.16136	.16435	.16734	.17033	.17332	.17632	80
10	.17632	.17932	.18233	.18533	.18834	.19136	.19438	79
11	.19438	.19740	.20042	.20345	.20648	.20951	.21255	78
12	.21255	.21559	.21864	.22169	.22474	.22780	.23086	77
13	.23086	.23393	.23700	.24007	.24315	.24624	.24932	76
14	.24932	.25242	.25551	.25861	.26172	.26483	.26794	75
15	.26794	.27106	.27419	.27732	.28046	.28360	.28674	74
16	.28674	.28989	.29305	.29621	.29938	.30255	.30573	73
17	.30573	.30891	.31210	.31529	.31850	.32170	.32492	72
18	.32492	.32813	.33136	.33459	.33783	.34107	.34432	71
19	.34432	.34758	.35084	.35411	.35739	.36067	.36397	70
20	.36397	.36726	.37057	.37388	.37720	.38053	.38386	69
21	.38386	.38720	.39055	.39391	.39727	.40064	.40402	68
22	.40402	.40741	.41080	.41421	.41762	.42104	.42447	67
23	.42447	.42791	.43135	.43481	.43827	.44174	.44522	66
24	.44522	.44871	.45221	.45572	.45924	.46277	.46630	65
25	.46630	.46985	.47341	.47697	.48055	.48413	.48773	64
26	.48773	.49133	.49495	.49858	.50221	.50586	.50952	63
27	.50952	.51319	.51687	.52056	.52427	.52798	.53170	62
28	.53170	.53544	.53919	.54295	.54672	.55051	.55430	61
29	.55430	.55811	.56193	.56577	.56961	.57347	.57735	60
30	.57735	.58123	.58513	.58904	.59297	.59690	.60086	59
31	.60086	.60482	.60880	.61280	.61680	.62083	.62486	58
32	.62486	.62892	.63298	.63707	.64116	.64528	.64940	57
33	.64940	.65355	.65771	.66188	.66607	.67028	.67450	56
34	.67450	.67874	.68300	.68728	.69157	.69588	.70020	55
35	.70020	.70455	.70891	.71329	.71769	.72210	.72654	54
36	.72654	.73099	.73546	.73996	.74447	.74900	.75355	53
37	.75355	.75812	.76271	.76732	.77195	.77661	.78128	52
38	.78128	.78598	.79069	.79543	.80019	.80497	.80978	51
39	.80978	.81461	.81946	.82433	.82923	.83415	.83910	50
40	.83910	.84406	.84906	.85408	.85912	.86419	.86928	49
41	.86928	.87440	.87955	.88472	.88992	.89515	.90040	48
42	.90040	.90568	.91099	.91633	.92169	.92709	.93251	47
43	.93251	.93796	.94345	.94896	.95450	.96008	.96568	46
44	.96568	.97132	.97699	.98269	.98843	.99419	1.0000	45
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COTANGENT

NATURAL TANGENT

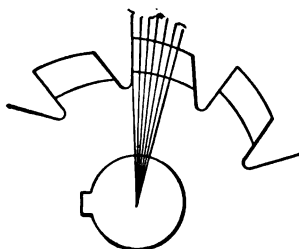
Deg.	0'	10'	20'	30'	40'	50'	60'	
45	1.0000	1.0058	1.0117	1.0176	1.0235	1.0295	1.0355	44
46	1.0355	1.0415	1.0476	1.0537	1.0599	1.0661	1.0723	43
47	1.0723	1.0786	1.0849	1.0913	1.0977	1.1041	1.1106	42
48	1.1106	1.1171	1.1236	1.1302	1.1369	1.1436	1.1503	41
49	1.1503	1.1571	1.1639	1.1708	1.1777	1.1847	1.1917	40
50	1.1917	1.1988	1.2059	1.2131	1.2203	1.2275	1.2349	39
51	1.2349	1.2422	1.2496	1.2571	1.2647	1.2723	1.2799	38
52	1.2799	1.2876	1.2954	1.3032	1.3111	1.3190	1.3270	37
53	1.3270	1.3351	1.3432	1.3514	1.3596	1.3680	1.3763	36
54	1.3763	1.3848	1.3933	1.4019	1.4106	1.4193	1.4281	35
55	1.4281	1.4370	1.4459	1.4550	1.4641	1.4733	1.4825	34
56	1.4825	1.4919	1.5013	1.5108	1.5204	1.5301	1.5398	33
57	1.5398	1.5497	1.5596	1.5696	1.5798	1.5900	1.6003	32
58	1.6003	1.6107	1.6212	1.6318	1.6425	1.6533	1.6642	31
59	1.6642	1.6753	1.6864	1.6976	1.7090	1.7204	1.7320	30
60	1.7320	1.7437	1.7555	1.7674	1.7795	1.7917	1.8040	29
61	1.8040	1.8164	1.8290	1.8417	1.8546	1.8676	1.8807	28
62	1.8807	1.8940	1.9074	1.9209	1.9347	1.9485	1.9626	27
63	1.9626	1.9768	1.9911	2.0056	2.0203	2.0352	2.0503	26
64	2.0503	2.0655	2.0809	2.0965	2.1123	2.1283	2.1445	25
65	2.1445	2.1609	2.1774	2.1943	2.2113	2.2285	2.2460	24
66	2.2460	2.2637	2.2816	2.2998	2.3182	2.3369	2.3558	23
67	2.3558	2.3750	2.3944	2.4142	2.4342	2.4545	2.4750	22
68	2.4750	2.4959	2.5171	2.5386	2.5604	2.5826	2.6050	21
69	2.6050	2.6279	2.6510	2.6746	2.6985	2.7228	2.7474	20
70	2.7474	2.7725	2.7980	2.8239	2.8502	2.8770	2.9042	19
71	2.9042	2.9318	2.9600	2.9886	3.0178	3.0474	3.0776	18
72	3.0776	3.1084	3.1397	3.1715	3.2040	3.2371	3.2708	17
73	3.2708	3.3052	3.3402	3.3759	3.4123	3.4495	3.4874	16
74	3.4874	3.5260	3.5655	3.6058	3.6470	3.6890	3.7320	15
75	3.7320	3.7759	3.8208	3.8667	3.9136	3.9616	4.0107	14
76	4.0107	4.0610	4.1125	4.1653	4.2193	4.2747	4.3314	13
77	4.3314	4.3896	4.4494	4.5107	4.5736	4.6382	4.7046	12
78	4.7046	4.7728	4.8430	4.9151	4.9894	5.0658	5.1445	11
79	5.1445	5.2256	5.3092	5.3955	5.4845	5.5763	5.6712	10
80	5.6712	5.7693	5.8708	5.9757	6.0844	6.1970	6.3137	9
81	6.3137	6.4348	6.5605	6.6911	6.8269	6.9682	7.1153	8
82	7.1153	7.2687	7.4287	7.5957	7.7703	7.9530	8.1443	7
83	8.1443	8.3449	8.5555	8.7768	9.0098	9.2553	9.5143	6
84	9.5143	9.7881	10.078	10.385	10.711	11.059	11.430	5
85	11.430	11.826	12.250	12.706	13.196	13.726	14.300	4
86	14.300	14.924	15.604	16.349	17.169	18.075	19.081	3
87	19.081	20.205	21.470	22.904	24.541	26.431	28.636	2
88	28.636	31.241	34.367	38.188	42.964	49.103	57.290	1
89	57.290	68.750	85.939	114.58	171.88	343.77	∞	0
	60'	50'	40'	30'	20'	10'	0'	Deg.

NATURAL COTANGENT

Second, when tooth edge breaks it practically invalidates the whole cutter. This limit is about 7"; after this size is exceeded, the inserted-tooth milling cutter takes its place.



FIG. 121.—Forms of Fly Cutter.



Formed Cutter

FIG. 122.—Lines Indicating Repeated Grinding without Affecting Size and Shape of Cut.

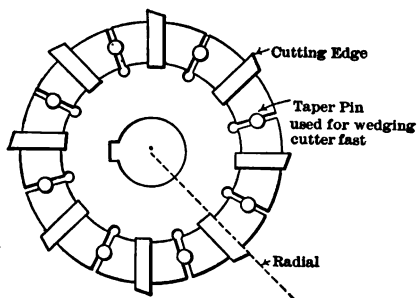


FIG. 123.—Inserted Tooth Cutter.

This is a built-up cutter where small pieces of tool steel only are required, and the body of the cutter may be made from cheaper material, such as cast iron or soft machinery steel, and in case of breakage of tooth edges, the expense of renewing is reduced to a minimum, Fig. 123.

When a very wide cut or several different planes and shapes are produced at once, several cutters are gauged, and term *gang milling* applied as in Fig. 116. On broad surfaces, when the plain milling cutter is used, the teeth

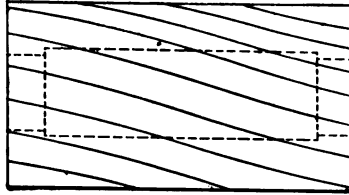


FIG. 124.—Spiral Mill, Showing Internal Construction.

are cut on a spiral, which gives a *shearing* cut, requiring the minimum energy, for the reason that the teeth or files are at an angle.

Note that the cutter is recessed, leaving only end bearings to fit arbor. Economic considerations—that is, what occurs during the hardening and tempering process—enter

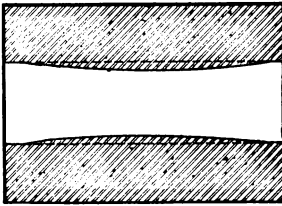


FIG. 125.

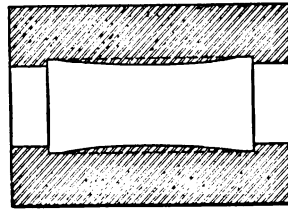


FIG. 126.

into the construction, and every mechanic should be familiar with these.

When cutter is plunged in the hardening solution, the outside only comes in contact with the chill of the solution, the inside being still hot. The chill effects a contraction on the outside while the inside is still expanding, resulting in a distortion of the cutter, as shown in Fig. 125, which

would require either lapping or grinding out, consuming unnecessary time, and requiring exceedingly high-grade skill, for it is essential that the cutter should fit the arbor perfectly without any tendency to rock, by recessing; only the end bearing need be finished, requiring the minimum time, and at the same time assuming the longest possible bearing on arbor. Fig. 126.

Number of Teeth on Cutters. Practice varies in this respect, the English practice running to finer teeth than the American.

There are two sides to the question, the difference being the number of cutting teeth; but in addition to this must be considered the resistance created by the increased number of cutting points, which limits depth of cut and feed; the coarser teeth, having fewer points and greater clearance, give possibilities of greater depth of cut, with energy of drive.

In English practice the circumference of the milling cutter, *being machined*, is divided by .28; in American practice by .40, as for example in making a cutter of 3" diameter.

$$\begin{array}{r}
 3 \times 3.141 = 9.423. \\
 .28) 9.423 \text{ (33.6 teeth)} \\
 \underline{84} \\
 102 \quad 34 \text{ teeth} \\
 \underline{84} \\
 183 \\
 .40) 9.423 \\
 \underline{235} \text{ or 24 teeth.}
 \end{array}$$

Method of Setting Cutter to Mill the Spiral. The angular cutter is used usually with faces 12" and 48", forming 60° angles, and the cutter is set 1/10 of the diameter of the work off center, bringing the 12° side radial which is desirable.

The center line of the cut must be obtained *before* swinging the lathe at the desired angle.

The width of cutters for milling the spiral in twist drills varies among the different manufacturers, but in each case the increase in width of cutter is in direct proportion to the increase in diameter of drill to be cut, as indicated on chart, Fig. 128.

From the accompanying chart the approximate width of the cutter to be used in milling twist drills is 60% of the diameter of the drill to be cut, or $\frac{3}{5}$.

Example: a drill 1.000 in diameter would require .600 wide; however, this approximation cutter is used, which

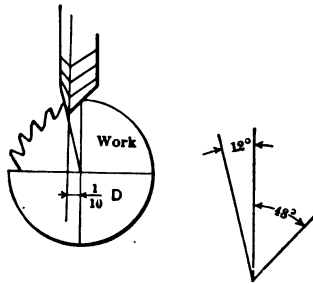


FIG. 127.—Cutters for Twist Drills.

leaves the cutting edge and the heel with the same angle. The theory has been advanced that in backing out it breaks the chip, thereby preventing the breakage which often occurs from this binding effect.

Two general forms are quite common, as shown in Figs. 129 and 130. In using cutter *M*, the distance marked (*X*) from side face of cutter is $\frac{1}{10}$ the diameter of the work to be cut. The depth of cut for this special cutter is .23 diam.

An approximate setting when using cutter *N* is to set face of cutter $\frac{1}{4}$ of the diameter of the tap to be cut. Depth $\frac{1}{8}$ diam. is only for use when no lathe table of cutters is handy to refer to. In most shops a table is posted.

The center line of the cutter is placed directly over the

center of this drill *before* the table is swiveled to the correct angle. One method of arriving at this center line of work is to bring the cutter to within a few thousandths of the work, using stiff paper to feel the contact envelope or writing paper about .004 to .005 thick, and pass the cutter over center until paper contact is obtained; then use the

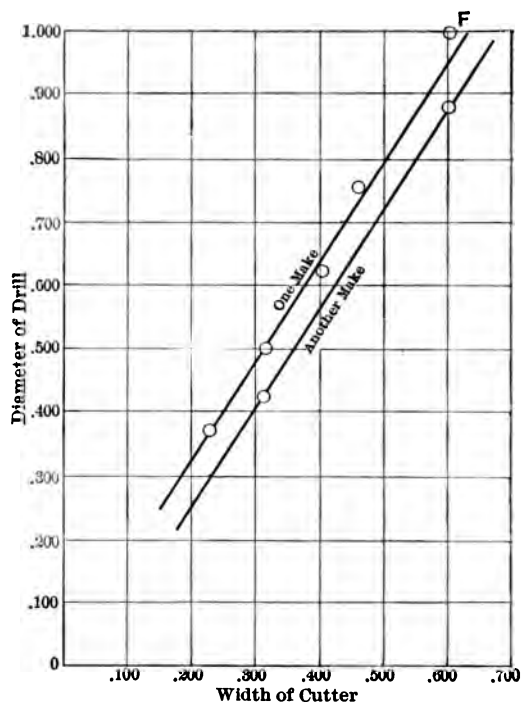


FIG. 128.

vertical screw micrometer, advancing .001 at a time, each time passing the cutter over the work. Finally a hair line will appear on the direct center of the work, to which bring the center line of the cutter. The depth of the cut is approximately $\frac{1}{10}$ of the radius. I say approximately because there is considerable variance among manufac-

turers. Again, the use for which the drill is intended is an important factor in considering the thickness of point.

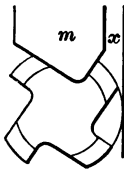


FIG. 129.

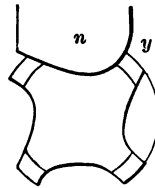


FIG. 130.

According to all practice this thickness increases as the drill becomes shortened through grinding and breakage.

Different Cutters for Different Uses. Cutters for fluting

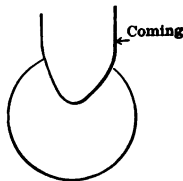


FIG. 131.

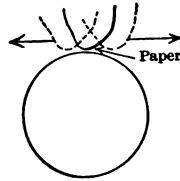


FIG. 132.

Shape of Cutter for Milling Flutes in Twist Drills.

taps; cutters for fluting reamers; cutters for end mills; cutters for angular cutters; slab or face-milling cutters, usually ganged.

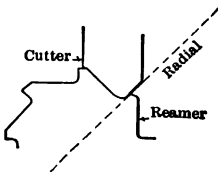


FIG. 133.



FIG. 134.

Various shapes are used for fluting taps, according to the whim of the manufacturer; sometimes a round cutter (*M*) is used also for fluting reamers when a modification of these figures becomes necessary.

The short angle of the cutter should be set so that its plane will pass through the center of the work, and the depth of cut gauged according to the land, or with face on cutting edge.

In fluting *end mills*, while a 70° cutter is usually used, an 80° cutter will give a stronger tooth and more mechanical effect, due to a certain amount of lost motion always found in a machine screw. The cutter should always run in a direction away from the cut and not toward it, as indicated in Fig. 135.

In using any milling cutters, especially saws and slot milling cutters, prove the thickness of cut by making a cut in a piece of cast iron or other material and file a piece

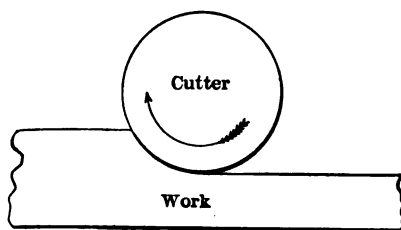


FIG. 135.

of brass to fix it, and then use micrometer, but *do not* rely on measuring the cutter with a micrometer, because there is grave danger of the cutter not running perfectly true sidewise, and this will give a cut wider than the indicated micrometer reading.

In setting a sawcutter for a key way on the center, this is a good means of proving the accuracy of the setting of the cutter by putting some old piece in the machine or centers, milling a slot and turning work end for end and trying the cutter in the slot.

Never take anything for granted; always prove your work.

Speeds and Feeds of Milling Cutters. So many varying conditions must be considered that it is impossible to give

figures that could be of any value to the mechanic. The time element is a factor that is too often ignored, and while there are many tables of speeds and feeds now extant, experience has proven how little value can be attached to them.

There is cast iron and cast iron.

There is steel and steel.

In one case it would be perfectly feasible to run 80' per minute with 10 or 12" feed for a definite cut, say .040 on length of cut of $1\frac{1}{2}$ ".

Increase the depth of cut to .080 and length of cut to 6" where the cutter remains in contact a longer period of time, and it will be found economy to cut down the speed to say 60 feet/m and a feed of 2 inches/m.

Milling cutters are expensive, and where the keen cutting edge is once gone it will not cut, but simply pene the metal and rack the machine. So it is always safe and economical to have the feeds and speeds well within the economic zone, because the time required to do the work is not the only item upon which is based cheap production, but the life of the cutter and depreciation of the machine tool as well, to say nothing of the overhead charges. Years of experience with many kinds of materials and tool steels would fix the following values as much nearer the economic than many of the tables usually given:

Annealed tool steel .. 28 feet/m feed 6/m.

Soft steel 42 feet/m feed 8/m.

Cast Iron 50 to 60 feet/m feed $1\frac{1}{2}$ /m.

Brass 90 to 100 feet/m feed 2/m accord-
ing to its alloy.

Bronze 78 feet/m feed $1\frac{1}{2}$ /m.

CHAPTER XIII

MEASURING INSTRUMENTS

Micrometer and its use. How to read it. Basis of calculation. The vernier and its use. How to read. Basis of calculation. Conversion table. Measuring blocks, and how constructed and used. Table of decimal equivalents.

Micrometer. This machine is designed for very accurate measurement, and should be a tool in the hands of every mechanic and every beginner.

The day of the two-foot rule is past. We now talk in thousandths of inches instead of sixteenths, and it is well to learn to think in thousandths, because it helps to form habits of precision and care that the successful man needs.

Fig. 136 shows the common type of micrometer, but micrometer measurements can be made in very many ways other than with this particular type. Any two numbers multiplied together which gives a product of 1000 is the basis of the micrometer system.

Fig. 137 is a screw of 10 threads per inch with a disc *a* fastened to it; disc graduated in 100 parts will give micrometer measurements, that is, the point of the screw will advance .001 when the disc is rotated one graduation mark.

The type of tool as represented by Fig. 136 has 40 threads per inch on spindle and is graduated on the barrel or sleeve *a* into 25 divisions = $40 \times 25 = 1000$; one turn of the barrel *a* advances the spindle which is attached to it .025 on the extension *b*, over which the barrel slides. You will note the small divisions as represented at *c*, each one of which represents 1 turn of the barrel, or .025; 4 turns of the

barrel, or .100, is represented by the long line at 1; 8 turns or .200 by the long line at 2, and so on up to the inch, or 1.000.

The rotation of the barrel is toward you to increase the reading; away from you to decrease it.

Now the barrel is marked 0, 5, 10, 15, 20, as in Fig. 4.

In Fig. 139 is represented a micrometer to which the beginner can readily apply the text and learn the reading.

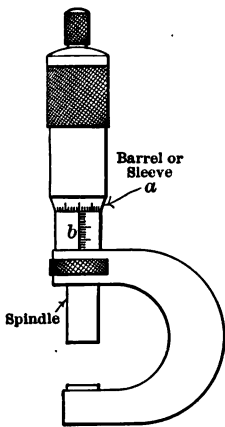


FIG. 136.

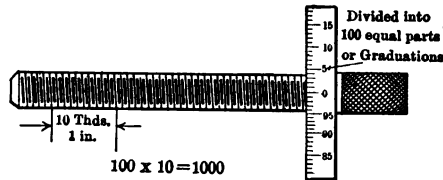


FIG. 137.

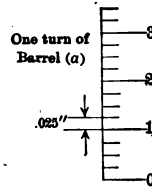


FIG. 138.

Each of the small spacings between 0-1 represents one turn of the barrel m , or .025; there are in this cut 14 of these spaces uncovered, and $14 \times 25 = .350$, the correct reading.

Fig. 140 is a fractional reading. There are in this cut five of these smaller or .025 spaces and a fraction of another uncovered.

$5 \times .025$ plus the fraction which is indicated by $5 + 2 = 7$.

$$\begin{array}{r} 5 \\ \hline .125 \\ .007 \\ \hline .132 \end{array}$$

Now, as the barrel is rotated in the direction of the arrow, more of the mark is discovered, and as the reading on the barrel is increasing in that direction until the 0 line coincides with the line of reading on the stem *g*, then 6 of the full divisions will be uncovered; 6 times .025, or .150, is the reading.

In reading the micrometer it is well to learn the important point that, as the barrel rotates toward you, you always

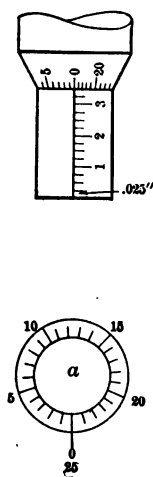


FIG. 139.

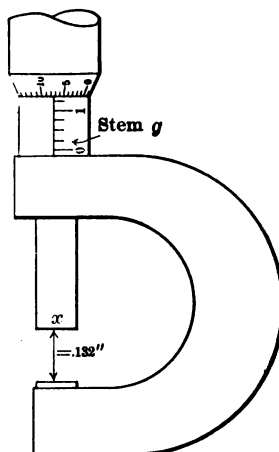


FIG. 140.

add the fractional turn as indicated on it, to the stem readings. That is, $125 + 7$; the next graduation would be 8, the next 9, next 10; and so on, as you rotate it away from you or close the gap between points you deduct the barrel reading. That is, by rotating the barrel, in Fig. 5, in opposite direction to the arrow, the reading edge of the sleeve would approach nearer and nearer the fifth mark on the stem, until the 0 would align; you then subtract the .007 from the .132, leaving .125. Turn still further until the 20 mark aligns, subtract .005 more, leaving .120 as measurement between points *x* and *y*.

The micrometer should never be used on work while the work is revolving. Stop the machine and use the little knurled extension on the top of the barrel to close it when the right size is obtained. The little knurled sleeve will slip, thereby avoiding the possibility of springing the instrument.

Remember that the micrometer is not designed to take the place of a monkey wrench; it is a calibrating device only.

Any mechanic can attach micrometer readings on lathe, planer, shaper, or any of the other machine tools in the shop, and it will pay, too. First get the pitch of the screw which moves the tool or work. If it is 10, the number of graduations in the disc must be 100; the size of these graduations depends on the size of the disc; the larger it is, the wider apart each .001 will be. If the screw has 4 pitch, 250 graduations must be on disc; if 8, 125 for the disc and so on.

Vernier Caliper. This instrument, as shown in Fig. 6, consists of a sliding jaw which carries the vernier graduation, named after the French mathematician to whom we are indebted for this measuring instrument.

This vernier may be moved over the fixed scale which is graduated on the limb *a* of the instrument and gives readings of $\frac{1}{16}$ th of an inch on the limb and $\frac{1}{16}$ th of this amount on the vernier *b* which equals $40 \times 25 = 1000$ th inch on the vernier.

The limb is fixed and the sliding scale or vernier may be made to move past it by means of the small screw *c*. This vernier usually has one more subdivision for the same distance than the limb (say 25 divisions on vernier = 24 on the limb), but it may have one less.

Rule First. Read the last subdivision of the limb passed over by the zero of the vernier on the scale of the limb as the reading of the limb.

Second. Look along the vernier until a line is found

which coincides with the same line on the limb. Read the number of the line from the scale of the vernier; this is added to the reading on the limb as the total reading.

Fig. 141 is enlarged view of limb scale carrying vernier.

Each inch on limb is subdivided into 40 equal parts and each part represents .025 of an inch.

Now read along the limb scale and you will note that the zero on the vernier is beyond the 16th long line on the limb scale, which equals 1.600". Now it is necessary to get the vernier reading to add to this, as you note that

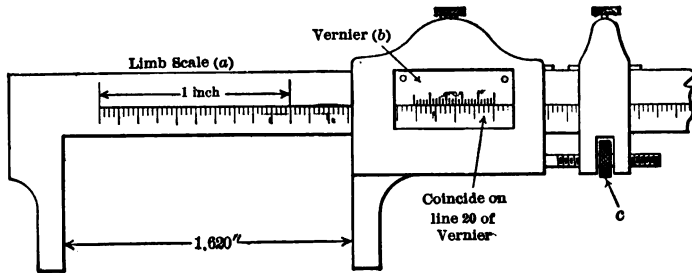


FIG. 141.

it divides two lines. Read along the vernier scale until you find that the line marked 20 in the vernier coincides with a line on the limb scale.

1.600
.020
1.620

inches is the reading or distance between the insides of the two jaws.

A little practice will enable you to read very accurately and very quickly.

This instrument has various adaptations, but it is commonly used as an outside caliper or height gauge.

The caliper square resembles the vernier caliper without the vernier graduation. They are not available when

extreme accuracy is required, but are used to a great extent where duplication is necessary, and when the number of pieces of work will not warrant the expense of a set of fixed gauges.

In many of our American shops to-day the Metric System of measurement is largely used, and the micrometer and vernier caliper are graduated to suit either the English or Metric System.

CONVERSION OF ENGLISH TO METRIC MEASURE

<i>English</i>	<i>French or Metric</i>
39.37 inches	1 meter
1 foot	.3048 meter
.3937 inch	1 centimeter
1 inch	2.54 centimeters
.03937 inch	1 millimeter
$\frac{1}{8}$ inch or approximately is designated as mm.	

It will be well for the mechanic to familiarize himself with both systems.

Measuring Blocks. It is very often desirable to have a piece of work very accurate as regards parallelism of openings or slots, or grooves, without the same regard as to exact measurement by a stipulated decimal size. As, for instance, a small cross head is required to slide between guides where the parallelism must be absolutely accurate, yet where the widths between guides need not measure to within a few thousandths.

Small pieces of steel of various sizes and shapes to suit required conditions are machined, hardened and lapped, and used as gauges. They are sometimes square, sometimes round bar steel, or at other times angular to fit dovetails, etc.

The use of the micrometer system of measurements is

TABLE OF DECIMAL INCH EQUIVALENTS OF MILLIMETERS

$\frac{1}{16}$ mm. = .00394"	8 mm. = .31496"	18 mm. = .70866"
$\frac{1}{8}$ " = .00787"	9 " = .35433"	19 " = .74803"
$\frac{3}{16}$ " = .01969"	10 " = .39370"	20 " = .78740"
1 " = .03937"	11 " = .43307"	21 " = .82677"
2 " = .07874"	12 " = .47244"	22 " = .86614"
3 " = .11811"	13 " = .51181"	23 " = .90551"
4 " = .15748"	14 " = .55118"	24 " = .94488"
5 " = .19685"	15 " = .59055"	25 " = .98425"
6 " = .23622"	16 " = .62992"	26 " = 1.02362"
7 " = .27559"	17 " = .66929"	

TABLE OF METRIC LINEAR MEASUREMENTS

10 Millimeters = 1 Centimeter.	1 Centimeter = .3937 Ins.
10 Centimeters = 1 Decimeter.	1 Decimeter = 3.937 "
10 Decimeters = 1 Meter.	1 Meter = 39.37 "

CHAPTER XIV

GEARING

Different kinds of gearing and their application to machine design.

Their various uses. Calculations for different kinds of gears.

Diametral pitch, circular pitch, linear pitch; worm wheel and worm rack tooth and its development.

THERE are many treatises on this subject covering many hundreds of pages, for the subject is scarcely exhausted in a single book, but there are a few simple principles which underlie and form the basis of these treatises that the machinist must be familiar with.

The term gearing is applied to positive driving mechanism, when through a train of gears machinery is put in motion, either to drive work or the tool; by *train* of gearing we mean the series of gears which make up the complete gear series.

Power is applied to the lathe, for instance, through its back gears, and 4 wheels or gears constitute the train, from the small gear on the end of the cone pulley, into the large gear on the back gear shaft, through its rotation into the smaller gear on the same shaft, and through it into the large gear on the main spindle of the lathe.

The word *spur* gear is used on all plain gears; when small they are called *pinion* gears.

Different Kinds of Gears. Spur, bevel, miter, worm, spiral, rack.

The spur gear is more commonly used, for transmission of power in machine tools.

The bevel gear is used to change the direction of motion at any angle.

The miter gear is a *bevel* gear, but the term is applied to a definite use of it.

NOTE: All miter gears are bevel gears, but all bevel gears are not miter gears.

Miter gears are gears of the same size, which always transmit motion at 90°.

Bevel gears may transmit motion at any degree, and may be and usually are two different sizes of gears. All of these have a well-defined shape of tooth that are identical.

A worm gear is a gear that is used to transmit great power, where speed of rotation is not considered, on the principle of raising a great weight by the wedge or inclined plane, as the angle of the tooth face of the worm acts as the wedge or inclined plane.

The spiral gears are gears that have straight face wheels with the teeth cut on a spiral and are used in various ways, as they can be run in any position or angle.

In gearing we speak of pitch, either diametral, circular, or linear.

The circular or linear pitch are practically alike, and is the term applied to the distance between the centers of two teeth on the pitch line.

What do we mean by the pitch line? It is the line where the teeth of two gears rolling together meet and pass each other as in Fig. 144.

It is the diameter of gear which is first obtained in the calculation, as, for instance, we desire to make a gear wheel with 31 teeth, 5 pitch. The 5 pitch is diametral, and means the number of teeth for every inch of diameter, hence,

$$\begin{array}{r} 5 \overline{) 31} \\ 6\frac{1}{2}'' \end{array}$$

or 6.2, is the diameter on the pitch line. Now to obtain the whole or outside diameter we must remember that

length of the working part of the tooth is divided by the pitch line, and as 2 pitches always equal the working depth of tooth, we must add $\frac{1}{8}$ to the pitch diameter.

Or, $6\frac{1}{2} + \frac{1}{8} = 6\frac{5}{8}$ or 6.6", as the whole outside diameter of gear blank.

Now the working depth of this tooth is $\frac{1}{2}$ or .4", and as $\frac{1}{16}$ of the working depth of tooth is considered good practice for clearance at bottom of tooth, we have

$$\frac{1}{16} \text{ of } \frac{4}{10} = \frac{1}{40} = .025.$$

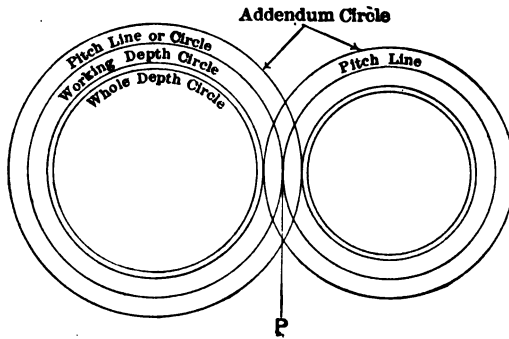


FIG. 144.

Now our calculations are:

31 teeth, 5 diametral pitch, which is all the data the mechanic will receive.

$$\begin{array}{r} 5 \overline{)31} \\ 6\frac{1}{2} = 6.2 \text{ pitch diameter.} \end{array}$$

6.2 + .4 or two pitches = 6.6 outside diameter for the machinist to turn it to, and if he has to cut it on the milling machine, he has

$$.400 + .025 = .425, \text{ the depth of cut.}$$

Rule. Divide the number of teeth by the diametral pitch for the pitch diameter of the wheel, add two pitches to this for the whole diameter.

The two pitches added always equals the working depth of tooth and $\frac{1}{8}$ of this is the amount added for clearance.

Now remember if it is 5 pitch, $\frac{3}{8}$ is added to the pitch diameter; if 6 pitch, $\frac{3}{8}$; if 7, $\frac{3}{8}$; if 8, $\frac{3}{8}$; if 9, $\frac{3}{8}$, etc.

Circular pitch, P , is the distance between the centers of two teeth measured on the pitch line, Fig. 145.

The process of calculation is the same, only in one case we figure from the diameter and in the other from the circumference.

Suppose we desire to make a gear 40 teeth with 1" circular pitch.

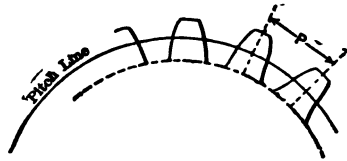


FIG. 145.

Now if we had a circle of known measurement on its circumference or outside, we could readily obtain the diameter by dividing it by 3.1416 or what is called "pi."

Now dividing by pi is the same as multiplying by its reciprocal or fraction, $\frac{1}{3.1416} = .3183$.

$$3.1416) 1.000000 (.3183.$$

$1 \times .3183 = .3183$, or a diameter pitch, and there are as many diameter pitches in a wheel as there are teeth, hence,

$$.3183 \times 40 = 12.732$$

$12.732 =$ pitch diameter, but we want the whole diameter and by adding the two pitches

$$\begin{array}{r} 12.732 \\ .3183 \\ .3183 \\ \hline 13.3686'' \text{ whole diameter.} \end{array}$$

Now $\frac{1}{16}$ of $2 \times .3183 =$ clearance, or some engineers calculate $\frac{1}{16}$ of the thickness of the tooth on the pitch line for clearance. In that case, if the circular pitch is the distance between the centers of two teeth, on the pitch line, it must equal a tooth and a space, or in other words, the thickness of tooth on the pitch line must be $\frac{1}{2}$ of the circular pitch, or

$$\begin{array}{r} .500 \\ \frac{1}{16} \text{ of } 500 = .050 \\ .550 \text{ full depth of tooth.} \end{array}$$

Bevel Gears are of necessity projected on a drawing board to scale, and the diameters thus obtained.

The teeth of these gears are formed about the frustrums of cones, whose apex are at the same points where the shafts meet. They are called pitch cones, because they roll upon each other and also the teeth are pitched upon them.

Brown & Sharpe's treatise on gearing gives a comprehensive knowledge of this important subject, showing how to project the gears.

Worm Wheel. A worm wheel is made to mesh with a screw called a *worm*. If the worm was cut in two on its axis it would show the teeth with straight faces similar to those of a rack.

Their axes are usually at right angles to each other.

The rules for circular pitch apply to the calculation for worm wheels, only the terms are sometimes misunderstood, because a worm may be double thread, triple thread, or quadruple, as the case may be; the term *pitch* may be misapplied. What really is essential is to know the advance of the worm thread, which is called the lead.

A single thread worm, for instance, with 3 turns to 1" is $\frac{1}{3}$ lead.

In *single* thread worm *only* is the lead and pitch the same.

The pitch is always the distance between the centers of two teeth on the pitch line.

Rule. Multiply the number of threads per inch on the worm by 3.1416, and we have as a product the diametral pitch of the worm wheel.

And having the number of teeth in the wheel and the diametral pitch, proceed as for spur.

These wheels are usually finished with a *hob*, a cutting tool that looks like a worm or screw with teeth for cutting purposes.

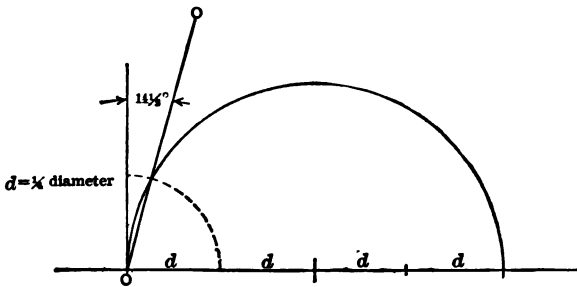


FIG. 146.

The diameter of hob for milling or hobbing a worm wheel should be a little larger than the worm—usually the diameter of the worm plus double the clearance of the tooth, and in making this we get the method of calculating the rack tooth tool, because the same tool would be necessary in cutting the worm or hob.

We speak of linear pitch or line pitch, because it is measured on the rack in a straight line.

Brown & Sharpe give the following method and calculation for obtaining the rack tooth.

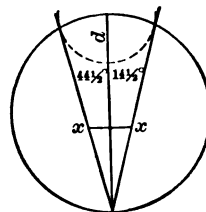


FIG. 147.

The sides of the rack tooth in the B. & S. gear is $14\frac{1}{2}''$, and to obtain this in a quick way draw any semicircle,

divide the diameter in four equal parts, set the dividers equal to one of these parts, and project it on the circumferences of the semicircle and draw the line OO , Fig. 147, through these points, which equals $14\frac{1}{2}^\circ$, or the side of a rack tooth. Then if this is true, to lay out for a tool to make the rack, we would draw a circle of any diameter and lay off $\frac{1}{4}$ of the diameter on both sides of the center line and draw lines as in Fig. 148. The width of tool point is the next calculation to obtain. This is equal to $.31$ of the linear pitch or P , hence if the pitch

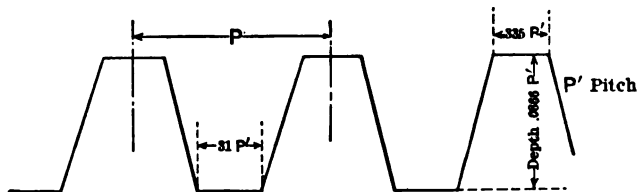


FIG. 148.

P was $1''$, $1 \times .31 = .31$ would be the length of line xx , and the tool form would be all ready to make.

If the linear pitch P were 1.25 we would have:

End of tool would be $.31 \times 1.25$.

Top of rack tooth would be $.335 \times 1.25$.

Depth of tooth would be $.686 \times 1.25$.

QUESTIONS ON GEARING

Define the distinction between miter gear and bevel gear.

Draw an outline of pair of bevel gears, running at 90° , indicating pitch diameter, face of tooth, thickness of tooth, and cutting angle.

Calculate size of pair of bevel gears:

32 teeth $5P$,

44 teeth $5P$.

Name the principal reason why the cutting by rotary cutter of a bevel gear gives only an approximation. Why is it not accurate?

How is the pitch of a worm usually given?

What is the angle of pressure on a worm?

How does it correspond to a rack tooth?

Calculate size of worm wheel to run with worm $2\frac{1}{4}$ " diameter, three threads per inch (single), 30 teeth.

What is a hob?

How much larger must hob be than worm?

Assume that a template is desired for gear teeth; 3 diametral pitch and 15 teeth.

What is meant by diametral pitch?

What is meant by circular pitch?

Calculate size of wheel.

Draw to some convenient scale, showing pitch, diameter, whole diameter, thickness of tooth, depth of tooth, and how you determine clearance.

Give method of setting cutters and slotting saws on center.

In cutting this same wheel, or template outline, what index circle and how many holes should be used?

What do you understand by simple indexing?

What is meant by compound indexing?

Calculate compound indexing for 69 teeth.

Calculate size and all dimensions for rack teeth for $1\frac{1}{4}$ " pitch.

Make sketch to scale of same and in ink.

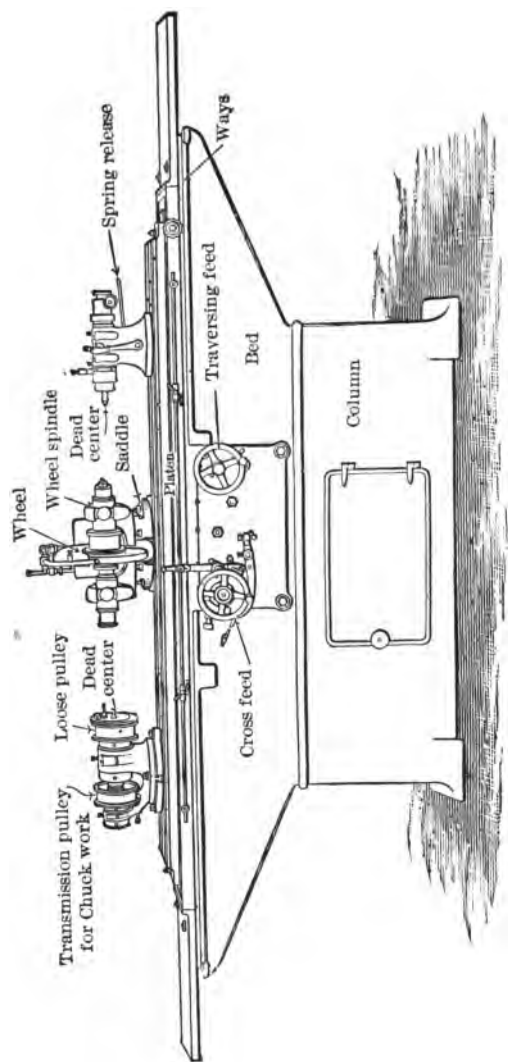


Fig. 149.

Column (C. I.)	Bed (C. I.)	Platen (C. I.)	Saddle (C. I.)	Abrasive wheel head	Wheel
				Two heads	Centers
				Traversing feed mechanism (C. steel)	
				Cross-feed mechanism (C. steel)	
				Transmission gears (C. I.)	

CHAPTER XV

GRINDING

Different types of machines and their uses. Materials for grinding.

Abrasives and the order of their cutting efficiency. Grain and Grade. Rules to be followed in mounting wheels, and why. Safe speeds. What limits the speed. Value of balance. How to increase speeds. Table of speeds.

Abrasives. Every boy has experienced at one time or another the value of abrasives without thinking much as to the theory. When the hands were stained with pitch pine or resin or other substances that would not yield to the ordinary washing soap, a handful of sand has proven the means of accomplishing clean results, and it was due to the sand as an abrasive that *cut* the dirt off.

The ordinary *sand grindstone* found in every shop is an abrasive wheel of the softer variety.

Emery is harder than sandstone; *corundum* is still harder than emery.

Carborundum is one of the hardest of abrasives, only exceeded in hardness by the diamond, the dust of which is commonly used as an abrasive by jewelers.

Alundum is still another abrasive of reputation that combines hardness, temper and sharpness.

It and carborundum are electric furnace products, fused at about 3000° F.

These abrasives are ground into various size grains for different gradings, passing through sieves of varying mesh, and being graded according to the number of threads or wires per linear inch of mesh.

As, for instance, 100-grain emery as abrasive passes through a sieve with 100 threads or wires per linear inch;

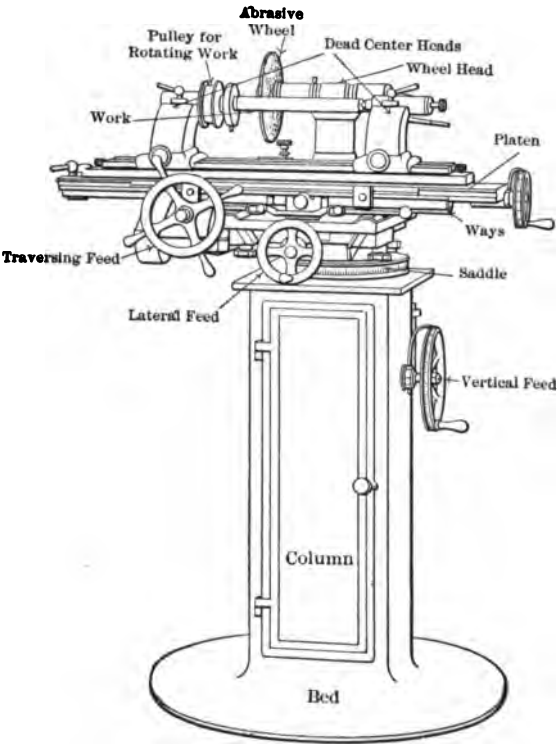


FIG. 150.—Norton Tool Grinder.

Bed (C. I.)	Column (C. I.)	Saddle (C. I.)	Platen or table (C. I.)	Head stock (C. I.)	Driving pulley (C. I.)			
			Lateral feed (Cru. steel)	Tool Stock (C. I.)	Centers (T. S.)	Work (Cru. steel)		
				Traversing feed (Cru. steel)	Traversing mechanism			
					Abrasive wheel head (C. I.)		Spindle (Cru. steel)	Wheel

90, 80, 70, 60, 50, 40, 30, etc., through respective sieves of like mesh. This determines the abrasive wheel's coarseness or fineness, as the case may be, but has nothing whatever

to do with the *grade*—this means the degree of hardness of the wheel.

The *grain* is the *size* of the cutting particle.

The *grade* is the temper of the grain, either soft or hard. A wheel that wears away rapidly is called soft, and vice versa.

These grains are mixed together with a bonding material that is in itself an abrasive after it has become vitrified or baked, and while this mixture is in a plastic state it is poured into moulds and placed in drying ovens for a short time. After this drying period they are made to size on special machines and again dried out.

They are then placed in ovens which are hermetically sealed and for a period of about 12 to 14 days, according to the size of the kiln, are subjected to varying degrees of heat, the highest being about 3000° F.

This intense heat fuses the bonding material and vitrifies it, and at the same time tempers the grain of the abrasives. They are then tested at about double the commercial speed, and thoroughly inspected.

Knowing now a little of the wheel construction and its constituents, we are still at sea as to their proper use, because so many conditions enter into their use that it has become a trade in itself.

First, the materials to be ground differ; iron, cast or wrought or malleable, brass bronze or alloys of any kind, steel of hard or soft quality, each of which need different handling. The amount of metal desired to be removed, whether from the rough or a few thousandths only for finish; the nature of the finish, and whether ground wet or dry—all of these conditions must be considered and the speeds and feeds made to conform to all.

It is well to get the advice of men who have spent their lives in developing this industry as to the grain, grade, speeds and feeds, for the work that is to be done, and save many heartaches and much money to the firm by so doing.

Two different men may work under practically the same conditions and one fails and the other succeeds.

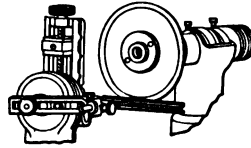
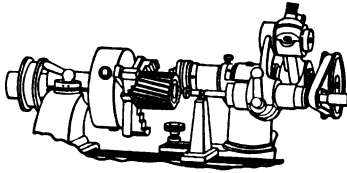


FIG. 151.—Method of Using the Internal Grinding Attachment, Ready to Grind.

FIG. 154.—Grinding Flutes in Taps.

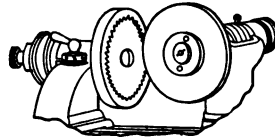
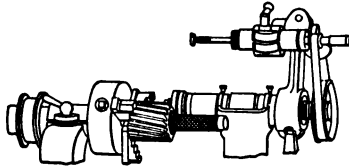


FIG. 152.—Shows Internal Grinding Attachment, Thrown out of Position for Purpose of Measuring Work.

FIG. 155.—Shows Method of Holding Saws and very thin Work by Means of Expansion Spindle.

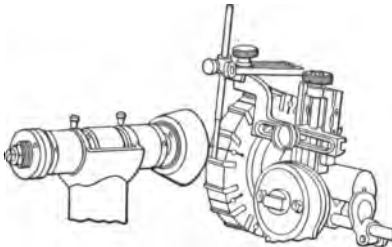


FIG. 153.—Cup when Used to Grind Inserted with Cutters.

FIG. 156.—Grinding Spiral Mill Showing Finger Stop.

SOME OF THE TYPES OF WORK DONE ON THE TOOL GRINDER (NORTON).

The manufacturers have different methods of tabulating their product as regards *grade*. The Norton Company of Worcester, Mass., designate their degree of hardness or

grade alphabetically in a sort of alphabetical progression, the beginning of the alphabet designating *soft* and the end of the alphabet *hard*. Carborundum wheels are tabulated by the reverse method—*hard* being designated by the beginning of the alphabet and soft by the ending of same.

As before stated, conditions vary so much that no absolute rule can be laid down for selecting the wheels as to proper grade and grain, but the following short table will act as an aid in forming a decision.

	Grain.	Grade.
Iron and steel castings	12 to 25	Q to U
Malleable castings	14 to 20	P to R
Chilled iron castings	20 to 30	O to U
Wrought iron castings	12 to 30	P to U
General machine shop use	24 to 46	O to P
Small tools	36 to 100	N to P
Reamers, milling cutters, etc.	46 to 100	JM
Wet tool grinding	46	J

Wherever it is possible the wheels should be covered with guards or hoods as a safety measure in case of breakage.

Fundamentals of Grinding. Grinding is a cutting process, each particle of abrasive being a cutting tool, with cutting edge as well defined as in any multiple-tooth cutter, and as the advantage of the multiple-tooth cutter over the single are admitted, we simply have a *multiple-tooth* cutter with an infinite number of teeth, and to get the highest efficiency from any multiple-tooth cutter, each tooth must have a chance to do its share of the work, which means that the abrasive wheel must run true. Hence in mounting a wheel, the *first* essential after it is properly mounted is to true the wheel by a thoroughly mechanical method that will insure trueness.

Do not try to hold a diamond or an emery wheel dresser in your hand in trueing a wheel, but have it rigidly fixed

and by means of the table or platen pass it across the face of the wheel; and it is advisable to have the wheel rotated by hand at a normal speed, rather than run it at its cutting speed, while the process of trueing is going on. The particles are not burned or fused then.

No mechanic can do good work on any machine unless he is thoroughly familiar with the conditions under which the machine operates at its highest efficiency.

He should know that the wheel has not been forced on the arbor, but fits freely without play. He should know that

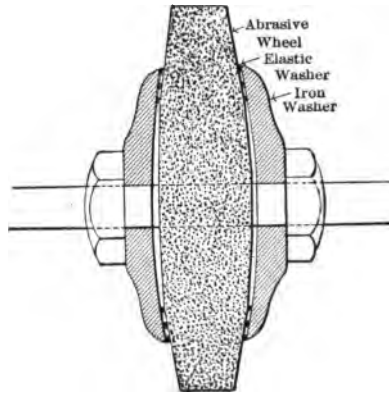


FIG. 157.

it has been properly cushioned to absorb shock, heavy paper (not hard), or thin rubber being used as the agent.

The washers should be large enough to hold firmly, a large side area of the wheel; they should be at least $\frac{1}{2}$ the diameter of the well, preferably larger, up to $\frac{3}{4}$ the diameter if the nature of the work to be done will allow it, and the washers should fit on their outer edges as in Fig. 157.

We are enabled to run at an extremely high speed, due to the many cutting edges, but in speed lies the greatest danger. Hence, the operator should make sure that the speed at which the machine is belted is within the safety

zone. A speed indicator is a necessary tool. The safe working speed should not exceed 5000 feet per minute.

It is essential that the direction of rotation of both wheel and work be correct; many mechanics have failed on this particular point who were well informed on other essentials. The work and the abrasive wheel must pass each other in *opposite* directions, as in Fig. 158.

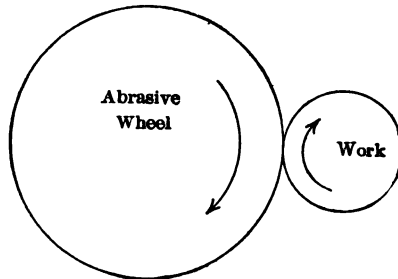


FIG. 158.

QUESTIONS ON GRINDING

In mounting an abrasive wheel, what precautions are necessary?

How is the jar on an abrasive wheel taken care of?

What is the first thing to do after mounting a wheel?

What is the advantage to trueing a wheel by hand?

What is the result on the work

(a) When the wheel is too soft?

(b) When too hard?

About what speed is safe for the general run of abrasive wheels used in the shops?

What is the advantage of speed in cutting?

How are wheels graded? Give general information as to grading of grain, etc.

Why is there a limit to the speed of an abrasive wheel?

By what means can this speed be increased and still retain a factor of safety to the operator?

Give grain and grade of wheels for grinding tool steel, cast iron and bronze.

Make sketch of wheel and show method of mounting that will prevent the wheel from flying out, if broken.

What is emery, corundum, carborundum?

Which is most efficient? Why?

What speed (surface) is safe practice for emery wheel, wet? Dry?

What speed for leather-covered wheels?

What is the disadvantage in not having proper feeds?

What is most important thing to do before grinding work?

What element of danger is to be safeguarded against? What are some of the methods you would consider in avoiding that danger?

How is carborundum and emery graded?

What letter indicates hard? Soft?

What is good grade for cast iron?

(a) What is good grade for soft steel?

(b) What is good grade for hard steel?

What is the advantage of grinding work on dead centers?

CHAPTER XVI

TOOL STEEL

Carbon and high-speed steels. Characteristics. Different kinds of steel and their properties. Different grades for different kinds of work. The determining factor in high-speed steel efficiency over the carbon steel.

STEEL is an alloy of iron. It is commercially pure iron, combined with certain other elements such as carbon, tungsten, manganese, chromium, nickel, etc. The proportion of these elements naturally determines the character of the steel.

Tool steel differs from what is termed mild steel in its contents of these various hardening elements.

The term mild steel differs from wrought iron in that it is free from slag; it entered the engineering field since the Bessemer and open hearth processes introduced the new class of iron which to-day is called low-carbon steel.

Up to about 1860 only three distinct classes were recognized: wrought iron, steel, cast iron.

The characteristic of wrought iron was its nearly complete freedom from carbon.

Steel was classified as such because of its carbon content, from .15 to 2 per cent.

Cast iron has a carbon content so high as to make it brittle whether cooled quickly or slowly.

The best class of steel was freed from slag by fusion in crucibles and poured into molds or cast, and received from the process the name of cast steel.

In the fused state all carbon is dissolved and is alike,

irrespective of its condition when the metal becomes cooled to a solid. The carbon may pass into different conditions, either as free carbon or graphite, as in the cast iron state, or it may pass into a definite iron carbide, or Austenite, which characterizes tool steel.

The steps by which we arrive from the iron ore to the higher grade of tool steel, are briefly traced as follows:

The ore is mined, and from it the iron is extracted by the process of smelting at a high temperature in blast furnaces, from which it is tapped or poured into molds forming "pigs."

The iron in these pigs is impure, to the extent of from 5 to 10 per cent of phosphorus, sulphur, silicon, etc.

From this pig iron, by a process of puddling, is produced wrought iron, by being puddled in furnaces the pigs are melted in contact with diluted oxides and stirred or robbed, until nearly all the impurities are oxidized or "burned out."

From the puddling furnace the ball of molten metals, about 75 lbs., sometimes more, is put through the rolls and squeezed and rolled into bars, called muck bars.

There is still the element of impurity in these bars, and these are cut into small pieces and made into oblong piles, reheated and rolled into merchant bars.

The purest ores are used to make the wrought iron which is to be converted into tool steel.

The wrought iron is rolled into certain adaptable shapes about $\frac{1}{2} \times 3$ ", cut up and placed in special boxes, and the pieces are separated from each other and from the box by hardwood charcoal, the top layer finally covered with the charcoal, the whole hermetically sealed with clay to exclude air, and the whole subjected to a high temperature for a long period of time, about 2000° F. for seven to ten days. The iron meanwhile absorbs the carbon from the charcoal in which it is packed and is converted into what is called blister steel, from its appearance when taken out of the packing. This is called the "Cementation Process."

The tool steel thus obtained is not likely to be homogeneous or uniform in texture, and therefore is not altogether reliable, although it can be improved by forging and working, and up to 1740, according to Benjamin Huntsman, it was the standard tool steel—carbon steel.

The process of manufacturing crucible tool steel as devised by Huntsman is to take the "blister" steel and break it up into small pieces, melt with certain fluxes in especially prepared clay crucibles, and heat to a certain temperature, at which it is maintained for a definite period and then poured or teemed at the precise moment into molds, forming ingots of crucible cast steel.

The method which is largely employed in the United States eliminates the cementation process. The wrought-iron bars are broken up and charged into graphite crucibles, graphite being rich in carbon, and from which the iron absorbs it together with other elements called medicine, such as manganese, carbon, etc. This process is capable of giving a steel of uniform quality and reliability. The great value of any tool steel lies in its uniformity; that is, the whole bar and all bars from that grade should give the same results under the same treatment, and many tool makers have learned by experience that it is wise to study a few brands only and obtain a thorough working knowledge, and then stick to them, although he may be called an old "fogy." Confidence in the steel that he is working is a big asset to a good tool maker.

Every manufacturer knows that the efficiency of his whole plant is, after all, dependent upon the cutting tools used, and a proper knowledge of the steel from which they are made,

HIGH-SPEED TOOL STEELS

There is a distinct line which should be drawn between self-hardening steel and high-speed steel, although they are commonly classified by the mechanic under the same heading.

This distinctive feature is that self-hardening steel hardens under the ordinary atmospheric temperature during its cooling process, while the high-speed steels are all subjected to a more or less elaborate treatment to effect their speed-cutting properties.

The author's experience with self-hardening steel dates back thirty years, with the use of "mushet" in a locomotive shop. This was followed closely by what was termed "chrome" steel which was used for the same purposes—hard materials—rather than for the economic one of speed. It is a comparatively short time since the introduction of the high-speed brands. The first really valuable experiments, one might say the first steps, in this advance were made by Mr. Frederick W. Taylor and Mr. Manuel White at the plant of the Bethlehem Steel Works in 1898 to 1900, the actual results of which were publicly exhibited at Paris along with other makers' steels.

This mushet steel was more of a manganese steel, the manganese aiding in the combination of the carbon with the iron. The chrome steel had chromium as the medium to bring about this result instead of manganese, and this was generally considered superior steel, owing to the results obtained.

Each brand of high-speed steel has its separate secret chemical composition, and only generally do we know and speak of them as made up of varying quantities of tungsten, molybdenum, manganese, chromium, carbon, and the later ones, vanadium, for which they claim still better results. As the percentage of these various alloys increases the

carbon element decreases; a large part of it combines with these elements at the high temperatures at which they are treated, forming carbides, which are very hard and are really the cutting teeth, if you please.

It is a matter of record that the speeds have increased considerably, even three or four times that of the ordinary carbon steels, and the mechanic is not nearly so interested in the chemical composition as he is in why this increased speed is possible; he wants to know what makes it, and that is really the only information that he really should have, to use them intelligently.

The difference might be summed up in a brief way by saying it is the different temperatures at which both kinds are treated, but the majority of mechanics do not see them treated and must solve the problem at the machine upon which he is operating. The same cause that will burn up the lubricant on the dead center of a lathe and create cutting—heat generated by friction—is responsible for it.

With both steels, the speed of the machine must be kept within a speed limit that will keep the heat which is generated by the friction of the chip and tool below the limit at which the tool was treated, which ranges from 1200° to 1500° F. for carbon steel, and 2000° to 2250° F. for high-speed steels.

Fig. 159 shows curve which was made at the time of the Taylor-White experiments by a Franklin Institute Committee, and shows clearly the action of temperature on both kinds of steel. The breaking-down point, or the temperature at which we would ordinarily destroy the efficiency by burning, is 1550° F. for carbon steels, while the point is not yet reached at 1900° F. for the high-speed steels.

High-speed steel as an economic factor is revolutionizing modern manufacture, and while it requires increased power to drive the machine tools, the return from greater production much more than compensates for this increase.

The real value of high-speed steels as an economic factor in production is not yet known, or to only a few at least, due to the fact that machines must be made to meet the increased stresses which are placed upon the different parts, and at present their use is confined mostly to the

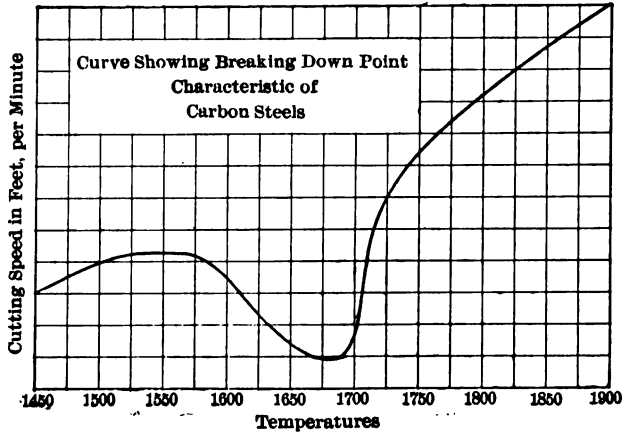


FIG. 159.

machines which were designed for carbon-steel tools. The different machine-tool builders are working to meet this demand, and when they do the figures we now have will become a matter of history.

CHAPTER XVII

TREATMENT OF TOOL STEEL

Annealing, forging, hardening and tempering. Water cooling by evaporation. Effect of sudden cooling. Cracking. Warping. Strains set up and why. Pack hardening.

So many conditions must be considered and observed as to make it practically impossible to fix a standard by which successful results will always obtain.

In the first place, the grade of steel as to its hardening contents should vary as the uses for which it is designed. A tool which is to be subjected to constant shock, such as cold chisels, should be of different material from that used to make a tool that will be used under a constant load; in short, *the one grade of steel is not adapted for all and every kind of tools.*

There are, however, certain principles which are fundamental that cannot in any case be ignored, such as slow, thorough heating, which insures uniform temperature throughout the whole piece, temperature of the cooling liquid, and time and method of drawing the temper.

Forced draught should not be used in heating tools for tempering because of the too rapid expansion of the metal, as well as the unevenness of the heated steel; the outside will be raised to the required temperature before the inside, which will result in strains that may crack the tool. Expansion and contraction should equalize and forced draught is apt to strain the particles beyond recovery of the contraction

The treatment of tool steel may be classified under four heads: Annealing, forging, hardening, tempering.

Annealing. Steel is annealed by slowly cooling from a low red heat. The longer the period of time that elapses in this cooling process, the more the strains that have been set up by rolling or hammering will be eliminated.

Primarily, annealing is the process of eliminating strains, and not to soften the steel. This softening of the steel is the result of by-product, if you please, that results from the heat treatment, in that it allows the carbon to separate and diffuse itself throughout the mass.

Annealing has become one of the laws of tool-steel treatment. Most of the makers of tool steel to-day anneal their product before sending it out to the trade. Whereas in years gone by it was thought that to anneal a piece of tool steel was to injure it to a certain extent, and by the methods used then it very often was true, because it was overheated or was cooled too quickly, or was allowed to cool in substances which tended to decarbonize it, or impart impurities to it.

Annealing improves the grain if properly performed.

Cast-iron annealing boxes are now used to a great extent, in which the product is packed in charcoal, ashes or any other substance which retains the heat, and sealed with fire clay, a period of time sufficient to allow the separate strains to adjust themselves being given. In the early days lime was used, because of its heat-retaining qualities.

Some tool makers and steel workers have become very proficient in the quicker method called "water annealing," where the steel is heated to a low red and held either in a dark corner until all color disappears or between dry pine boards until the steel fails to spark the wood, and then quenched.

A safe method to observe in working tool steel, especially if the mechanic does not know his steel, is to first rough out the tool and anneal it before finishing, and although

this may take a little more time, the final results in hardening and tempering will more than compensate for this loss. Nearly every tool-steel worker has experienced trouble at one time or another with steel that was improperly annealed, which left hard spots in the steel, these hard spots being the results of masses of combined carbon that have not been affected by the previous annealing, due perhaps to improper temperatures or method of cooling. Time is the element that cannot be ignored and is really more important than temperature.

There is very little excuse for meeting with hard spots in steel to-day with the advanced methods of conducting the annealing process in improved annealing furnaces where temperatures can be regulated, and when the time element is carefully regarded.

Forging. By forging we mean the heating and hammering of the metal, thereby causing it to assume a definite shape and size, and in doing this the same care must be exercised to secure the proper heat, and as in all cases that part of the bar to be forged must be uniformly heated, that is, heated clear through, the inside being the same as the outside.

The degree of heat depends on the size and shape of the piece and the carbon content, and the use to which the finished product will be adapted. Judgment must be used as to the force of blow when hammering—good hard blows if the piece is large and graduating down as it becomes smaller and cooler.

A piece of steel will be improved by proper hammering, as the density of the grain is increased, such piece being commonly known as hammer refined. If hammered below a certain temperature the grain is crushed and the steel is injured.

Now the part that has been forged may be only a small part of the tool; the rest of the steel has possibly been left untouched, and this causes what is called a forging strain.

due to different densities of the steel, and to relieve these the piece should be annealed after forging. This is a point worth our notice, that even a cold chisel or lathe tool or a screw driver gives far better results, if, after forging, it be reheated and allowed to cool slowly before heating for the hardening and tempering.

Hardening. This may be defined under three distinct heads:

First, the nature and composition of the metal, that is, the grade of steel.

Second, the temperature of quenching, or the refining heat, which depends almost wholly on the carbon content.

Third, the nature, volume, and temperature of the bath, which is determined from the piece to be hardened, the size, shape, and degree of hardness, or use to which it is to be subjected.

In this advanced age it may seem rather elementary to give any space to the subject of ordinary methods in hardening tool steel, but so much depends upon a thorough knowledge of a few of these elementals that it may be wise to consider them in this particular place, because every toolmaker will not have modern conditions under which to work; nor is it the man who, given the best conditions, can always do good work, that is so likely to succeed as the one who, miles from the shop, with a rush job on hand, creates his own conditions and produces results. Good results have been obtained even with soft coal, when no other facilities were to be had, although we know that soft coal with its inherent sulphur is not ideal. Fig. 160 illustrates the ordinary hand bellows forge of well-known type that has been prepared or is being prepared for tool-steel hardening.

The bottom of the forge has been cleaned out and a handful of pine shavings or waste put in, upon which a quantity of charcoal is placed. Upon this a block of wood is placed, the size depending upon the size and shape

of the tools to be hardened. A piece of gas pipe is laid upon this block in a vertical position as shown, for future vent. On this is packed the soft coal which has been crushed and thoroughly wet down to insure solidity in packing. The fire which starts in the shavings and waste underneath is transmitted to the charcoal and very little draught is needed to keep this burning. When finally the block of wood has been consumed, during which process the soft coal has been coked, a sort of muffler the size

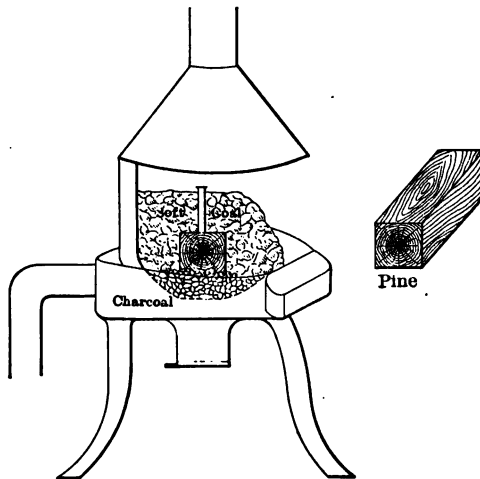


FIG. 160.

of the block of wood has been formed which will give very satisfactory heating conditions for small tools. It has certain muffler qualities such as heat-retaining walls, and needs very little draught to keep going. This matter of draught is important; if it were not so the muffler, perhaps, would never have been brought into use, to avoid the air coming in contact with the steel.

Forced draught should be avoided if you are compelled to use a forge. A slow heating allows for normal expan-

sion and gives us the right to expect the same contraction when the piece is cooled. Again the outside of the steel is brought to the refining heat before the center is brought to it. As to refining heat, every different temper of tool steel (I speak now of the manufacturer's term temper) has a different refining heat, which can be determined if you take a piece of the steel you wish to treat 6" or 8" long and $\frac{1}{2}$ " to $\frac{3}{8}$ " in diameter and with a file or tool of some kind nick it every $\frac{3}{4}$ " or inch, heat it so that one end will be near the melting point, and then let the heat slowly run down toward the other end, from the white or melting heat at one end to the black heat at the other, quench it and after drying it, break it, starting at the end with the



FIG. 161.

highest heat. It will be found that some one section between these two extremes was up to the refining heat. The overheated end will break very easily and show a coarse grain, as shown in Fig. 161.

The power to break these sections will increase as the black end of the steel is approached, but one section will show a very fine grain, which indicates the refining heat, and as the end is neared there is a tendency to bend before breaking, and the grain is coarse until we reach the natural grain.

It is plain from this that to overheat steel opens the grain, which will remain open until the steel is allowed to cool and again reheated to a refining heat. If by any chance in hardening a tool it has become overheated it is well to allow it to slowly cool and again reheat it to correct temperature and quench.

This question of refining is important, and only another way of saying again that the worker must know his steel, so that he would avoid using the refining heat for a .75 per cent carbon steel on a 1.6 per cent carbon steel and ruin it.

To avoid to a great extent the chances of error, where different grades of steel are in daily use, it would be well to mark the different grades with different color paints, each color denoting a different carbon content.

Gas Furnaces. To-day the hardening of tool steel has become a science, owing to the efficiency of the gas furnaces, which give those desirable results we have already mentioned, such as the even steady heat, eliminating the oxidizing influence of the air.

These are operated in many cases by ordinary illuminating gas, and the air is furnished by blower attachment so designed that the heat is generated by a properly proportioned mixture of gas and air. Their value lies in their always being ready; they are clean and very simple to operate.

Lead Bath. Another means that is used to a considerable extent for heating, especially small pieces, is the lead bath. The lead, which is melted in a crucible, should be chemically pure. The difficulty attendant upon this process is to maintain uniform temperature throughout the whole mass in the crucible, as it is possible to have the top of the mass at a higher temperature than the bottom. Stir occasionally with a perfectly dry rod. All of the pieces to be hardened should be perfectly dry to avoid spattering of the lead. Another danger is its tendency to evaporate. Lead at a temperature of 1200° to 1300° F. evaporates quickly, and to prevent this a thin layer of powdered charcoal should be used. To prevent the lead from clinging to the pieces, dip first in a strong solution of brine and thoroughly dry.

Cyanide of Potassium. Chemically pure cyanide of potas-

sium is used in a similar manner more perhaps to prevent all oxidization, especially where lower carbon steel is used and only surface hardening is required.

Cooling Baths. Many different cooling baths are used, the most common of which is water, although it is one of the poorest conductors of heat among the liquids.

Water cooling is attained by means of evaporation. The hot metal coming in contact with the water immediately converts the layer of water next to it into steam, this passes out into the body of the water and the next layer which comes in contact is again evaporated into steam and finally the heat is conducted from the heated piece. When the heat is excessive very often bubbles are formed which prevent the next layer from surrounding the tool wholly, and soft spots in the hardened piece is the result.

The more rapidly the heat is conducted from the steel by the hardening bath, the harder the steel will be, and this should point the way to the requisite temperatures, the extremes between ice-cold baths and warm baths, balanced, give the normal temperatures, about 65° to 70°.

The size of the bath is also important, as too small a receptacle means a quick change in temperature, which would defeat the desired results.

The cooling bath should be agitated; that is, if water is used it should be running water, and if this is not at hand, the water in the receptacle should be stirred or whirled around and the tool or piece to be hardened should be dipped in the vortex or center of this whirling bath, for equal absorption. Salts and acids increase the heat-conducting power of water. Common salt is mostly used as a soluble mixture to make a brine, usually enough of it to make a saturated solution—all that the water will dissolve.

Oils and fats are used to a great extent as hardening solutions, because they tend to make the steel less brittle than water. They have less hardening power, but give

the steel a toughness that water will not give. Neat's foot, lard, or fish oil may be used and will be found satisfactory for small tools, springs, etc.

For tools having projecting edges, such as reamers, end mills, spiral cutters, etc., oil is commonly used as a second bath, as the teeth need to be hard for about $\frac{1}{2}$ to $\frac{3}{4}$ their depth, and the tool being first dipped in water or brine for a short period of time and then plunged in oil and allowed to cool there; this serves a double purpose—that of holding the hardness of the teeth from the water chill and preventing a breaking strain. Some tool-makers use oil as a combined hardening and tempering process. It is better, however, to differentiate between the two processes, first hardening the tool and afterward tempering it.

A very common method is to use the water bath with oil on top, when the piece requires hardness but is liable to crack under sudden cooling shock. The oil through which the tool has to pass diffuses itself over the whole piece and prevents that sudden contraction that water alone would give.

As to the time of cooling, a safe rule to observe would be to time the vibrations or hissing; when all vibration or hissing ceases, the tool is as hard as it can be made, no matter how long it is held in the bath.

The metal mercury, the only metal that is liquid at normal temperature, is also used as a hardening agent, but its excessive cost and the dangerous fumes arising from it put it in a special class of hardening agents. Small dental tools are frequently cooled by this means. For very small drills, where extreme hardness is required, a potato will prove the best hardening agent, about 90 per cent being water and the other 10 per cent starch, and of the starch, about 40 to 50 per cent is carbon.

Sealing wax will prove a very good substitute for the potato for small drills and fine-point tools of extreme hardness.

Cold lead, a block of which is found around every machine shop, has been used with excellent results for flat drills, which, after heating, are driven down into the lead.

When many pieces of a kind are to be hardened, the process known as pack hardening is extensively used, when the pieces are packed in an iron box and surrounded with charred leather, bone dust, hoof parings, etc. The value of this is not only that a large number can be treated, but treated alike as to hardness, due to the possibility of even, thorough temperature.

Tempering. Hardening and tempering are too often confounded and used as the same term, to mean the same thing. Hardening drives the heat out. Tempering is accomplished by putting heat in. When the tool steel has been hardened, it is left very brittle and not usable until some of that brittleness has been removed and the metal toughened, or as we say tempered. The color scale of temperatures was long the standard for drawing the temper in tools for different uses, but is rather an approximate than a real value, because the difference in carbon content gives the different colors for fixed temperatures. A piece of tool steel which has been made very hard will, if dried, polished and held over a Bunsen flame, be affected by oxidization. A thin film of iron oxide will coat the whole piece and show different colors according to the different temperatures, from the light straw for reamers, taps, etc., to the dark blues for cold chisels and the greenish gray of natural temper. At 412° F. the first change begins to take place; that is, there must be put into the hardened piece of tool 412° of heat before any change is possible, and from that degree on the changes in molecular rigidity are effected according to varying temperatures.

The following table, or one similar, which has been handed down to us from our forefathers, will give approximate temperatures:

432° F.	Light Straw	Metal working tools for planer, lathes, etc. All tools for hard substances, such as ivory, bone, etc.
450° F.	Natural Straw	All teeth cutters, such as milling cutters, reamers, end mills, taps, etc.
470° F.	Dark Straw	Punches and dies. Wood bits. Tools for stone and marble.
490° F.	Brown	Wood-working tools generally. Ordinary temper for drills.
520° F.	Bronze	Saws. Springs. Small instruments.
550° F.	Purple	Screw drivers. Wood chisels and gauges. Cold chisels for metal.
570° F.	Blue	Wood saws and those tools on which it is desired to put edges with files, as wood centers, etc.
600° F.	Dark Blue	Easily filed.
632° F.	Greenish Gray.	Natural temper.

These colors are not guessed at in our present-day methods, as most of the tempering is now done in specially prepared tempering baths that are equipped with thermometers and where the heat can be thoroughly controlled. Heavy oil heated to the required temperature is used mostly in these baths and the hardened pieces put in; the length of time does not figure in the drawing as the temper after this bath heat has once reached all parts of the hardened tool. Hot sand is used for drawing small pieces in quantity. Long thin pieces are sometimes drawn in tubes or pieces of gas pipe which has been heated and

gives a uniform heat to all parts, which is necessary in any method of skill.

Methods of Dipping. This must be learned by the individual who is working tool steel. Certain results are demanded, such as straight work, refined steel, no change in form and outline, and the right temper.

One suggestion might be worth considering always, and that is that the most important factor in our treatment is controlled by the metal and not by the workman—expansion and contraction—and knowing this, the methods of approaching it must be in accordance with these laws. To take a few pieces as illustrations. A reamer, for instance, 7" or 8" long, after heating is plunged in the bath flat, so that the side along the entire length comes in contact with the bath; it will immediately contract on the side that first touched the water or bath, and the other part is still expanding up to the point at which it feels the chill. There is little question as to the shape when taken from the bath—a curved stem rather than a straight one. Again, take a wedge of any kind, a large knife blade for instance, and dip it with fine edge first, which sets the grain. When the larger area of the back begins to set it pulls the thin edge whether it wills and leaves anything but a straight-line edge. This would indicate at least certain considerations that are to be respected in immersing pieces in a bath.

The summary of the treatment of tool steel is to recognize the importance of stress strains and the value of annealing, and that time is the factor in this particular process rather than temperature; but remember that the annealing heat is a low heat;

That the refining heat should be gradually and slowly approached to allow a thorough heating of the steel;

That the bath should be of right temperature and according to the requirements of the use of the tool;

That a combination of oil and water gives tougher structure;

That in tempering the temperatures should be regulated according to the grade of steel used, and that the piece of work should be dipped with largest area first and in vertical position, and that the bath should be agitated.

QUESTIONS ON TOOL STEEL

What are some of the precautions necessary in handling tool steel preparatory to working it to size?

Why should extreme care be used in centering tool steel? Give effect and conditions which will occur if not accurately centered.

What effect have dull tools on tool steel in turning, shaping or milling machine work?

Why should all work be faced before turning?

Why do you anneal the piece after roughing?

What kinds of strains, and what do you mean by strains, which are set up in tool steel?

What effect has hammer blow on tool steel in straightening?

What is assumed when you speak of the proper amount which should be left for grinding?

Under proper tool conditions, what amount should be left?

How do you overcome hard spots in tool steel?

In annealing tool steel, how does the temperature compare with the hardening temperature? Is it higher or lower?

How should steel be heated for hardening? What care should be exercised?

Give method of hardening to obtain a tough, uniform temper; give reasons underlying each step.

How should tools be dipped, and what precautions should prevail, and what is the result if precautions are not taken?

Why is the end of a spiral end mill often recessed?

Give full directions for starting and shutting off the gas furnace.

Where is the hottest part of the flame in a Bunsen burner?

Give the color scale of temperatures for tempering different tools.

What is the difference between hardening and tempering?

What is the best method of plunging a piece in cold water?

What is a "muffle" furnace?

- What is a "muffle" used for?
- Why is oil used in hardening and tempering?
- What kind of steel is used in an Armstrong tool-holder?
- How should such a tool be ground?
- What danger is there in grinding a tool too heavily on an emery wheel?
- Can an Armstrong tool be "burned" in grinding?
- How is a blue finish obtained on steel with a Bunsen burner?
- Why is this blue finish useful?
- How would you bore an inside taper hole?
- What is meant by "lapping" a piece of work?
- What is the effect of forced draft in a fire in which you are heating tool steel?
- Why is a fire made of soft coal to be avoided?
- What effect has charcoal fire on steel?
- What is the proper way of heating steel for hardening?
- In heating steel, what is the most important detail?
- In hardening, what are some of the essential things to be considered, such as dipping to overcome warping?
- Give different baths for hardening and which is common in practice?
- What is the difference between hardening and tempering?
- If tempering in oil, what degree of heat is used?
- What method would you use to straighten a warped reamer and mandrel?
- What is carbon steel?
- What difference between it and superheated steel?
- What advantage has superheated steel over ordinary carbon steel?
- Is superheated steel efficient for finishing cuts? Give reasons for and against.
- What gives superheated steel its efficiency?
- How is it treated (commercially) in hardening?

CHAPTER XVIII

TOOL MAKING

PUNCH AND DIE

Punch press construction. Stock, different kinds. Punch construction. Die construction. Punch pad. Punch holders and their economic value. Stripper plates, closed, open and spring. Forming tools and their construction.

THE phrase tool making is very apt to mislead the mechanic as well as the layman, unless the type of tools that is embraced within the limits of this term is specifically stated.

It is true that mandrels, end mills, drills, reamers, milling cutters, etc., are tools used to reproduce their kind, and for general cheapening of production, but not for the economic reason solely, for the modern plant needs these general tools for production of product to meet competition. But the term tool making as understood in the trade is used to classify punch, die, jig and fixture work. They are cheap production tools, and here again this term, cheap production, is not to be misplaced and given the place of primary importance in their conception. The element of cheap production is secondary to the primal one of interchangeability.

The ability to produce a thousand or fifty thousand parts exactly alike is the greatest economic factor to the manufacturer who sells his product throughout the civilized world, and is called upon to replace parts of machines that have become worn or broken. What largely determines

the point between the usual method of developing pieces through the various machining operations and punch and die and jig and fixtures, is made up of several important factors.

The number of parts required is perhaps the most important of these factors, but in determining this, such considerations as standardization of apparatus, whether it is in the experimental stage, or has reached a fixed standard; whether there will be a demand for the apparatus, etc.—have a bearing on the quality of tools to be made, that is, whether cheap fixtures or expensive, permanent ones. If only a few pieces are necessary the difference between the use of machinery steel, case-hardened, and tool steel, will be determined in favor of the cheaper product.

There are many kinds of punch and die work, from the complicated sectional die to the commonest form of simple die, all of which have certain fundamental principles that the student, apprentice or machinist must learn before he can bring about successful results as a toolmaker. He must also know the machine or press upon which the work is to be done, how the tools are to be held in the press, how to set the punch and die for alignment, the value of solid bedding and why it is valuable, and with this general knowledge he will be able to proceed in preparing the materials that build up the whole.

Fig. 162 shows a typical modern punch press with the names of different parts, which are indicated in the building up diagram immediately below. Fig. 163 shows details of clutch and tripping mechanism which controls the strokes of the press.

FIG. 162.—E. W. Bliss Press.

Legs (C. I.)	Bed	Bed plate (C. I.)	Bolster (C. I.)	Die (T. steel)
	(C. I.)	Automatic feed rolls	(Cru. steel)	
	Tripping mechanism	(C. I. and Mach. steel)		
	Housing	Ways	Ram of plunger	Punch holder
	(C. I.)	(C. I.)	(C. I.)	(Cru. steel or I. C.)
	Main spindle	Fly-wheel	Bronze bushing and steel keys	Punch, (T. steel)
	(Cru. steel)	(C. I.)	Clutch (Cru. steel)	

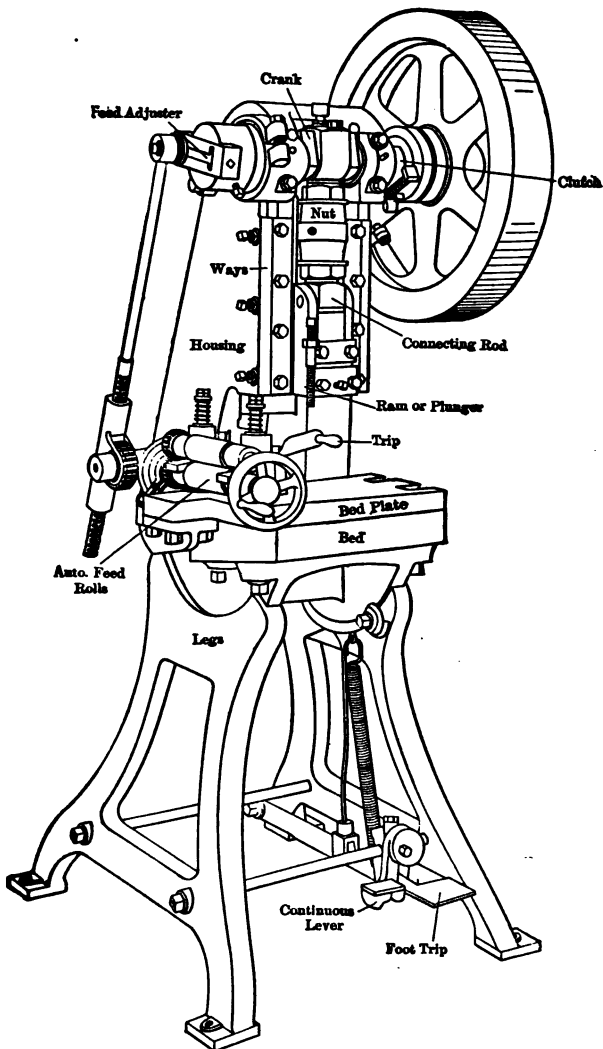


FIG. 162.—E. W. Bliss Press.

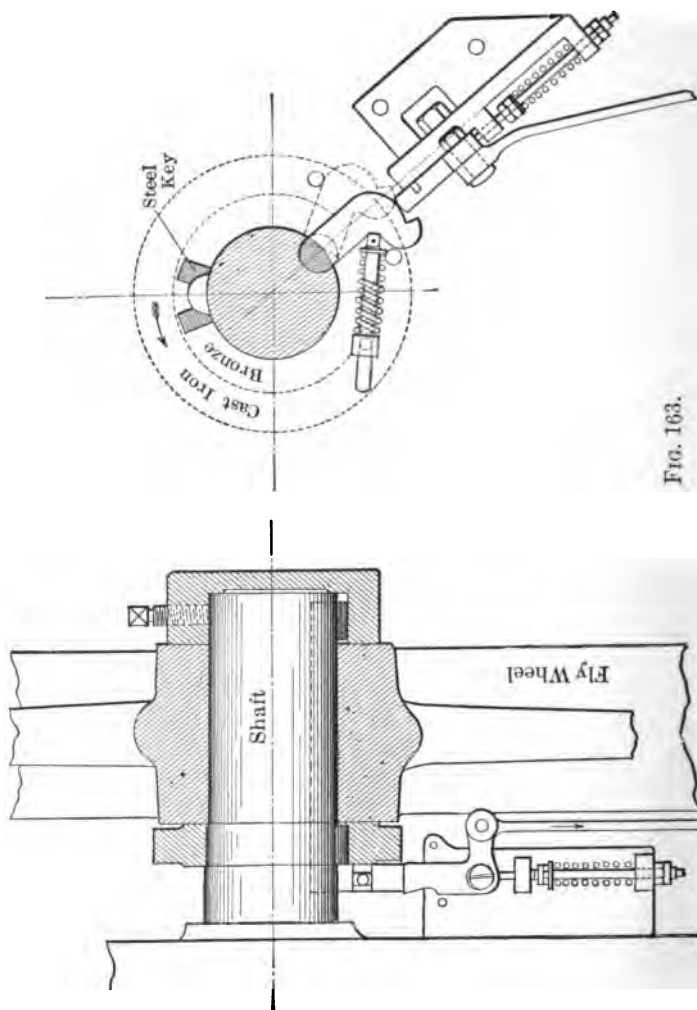


FIG. 163.

Materials of Punch and Die Construction. The different parts that are used in punch and die construction are classified under the following names:

Bed plate of machine	Cast iron
Bolster	Cast iron
Die stock, usually	Tool steel
Stripper plate	Iron or soft steel
Punches	Tool steel
Punch pad	Soft steel or cast iron
Punch holder	Soft steel

The bed plate holds the bolster, which in turn holds the die. The punch holder holds the punch pad, which in turn holds the punches. The value of the punch pad and its real economic function lie in being able to have a wide range of punch pads with a very few holders. To make this feasible the punch holder and punch pads should be so constructed that they are interchangeable.

The function of the stripper plate is to strip the metal from the punch as it ascends. There are many ways of stripping metal from the punches. Some of the stripper plates are held in the die while others are held on the punches, the latter being termed spring strippers. The screws which hold the pad to the holder should not be expected to keep alignment perfect; dowel pins should be used in every case for this purpose.

Bolster. This is usually made of cast iron and machined with true bottom face. The opening in which the die is held is machined as a dovetail of varying width to suit conditions of the stock. The purposes of this dovetail construction is to insure perfect bedding of the die, as any pressure which is brought to bear upon the sides of the die, either by key or set screws, tends to force it down the incline. The angles of these sides are from 7° to 10°.

Simple Forms of Punches and Dies. To more clearly comprehend the construction from raw material to finished

product, two or three simple dies are illustrated in this building-up process, clearly showing the principles that are fundamental in all work of this class.

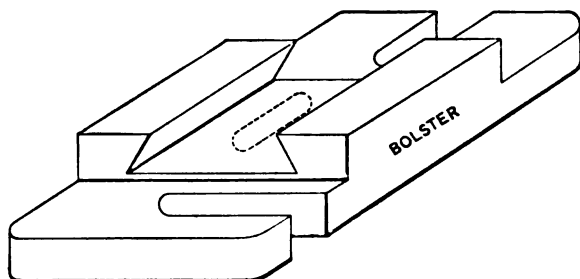


FIG. 164.

Fig. 165 shows method of preparing the stock for the simplest form of punch and die—a piercing punch with cutting-off tool. The angles on the side of the die stock are obtained by means of two parallel strips with 7' to 10° angular sides.

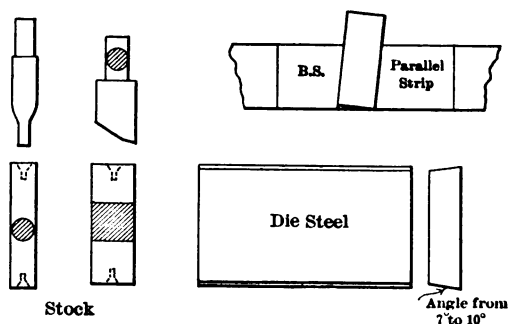


FIG. 165.—Detail of Punch and Die.

In machining a pair of these strips they should be made in one piece to insure like sizes all around, as well as like angles. It is then cut in two and is used in vise as shown in the illustration, Fig. 165.

Cutting-off Tool. The cutting-off tool is made of square tool steel, centered and turned down to fit some standard size hole in punch pad. The piercing punch as here outlined indicates turning, but in very many cases straight pieces of drill rod can be used without any machining at all.

In Fig. 166 the whole is assembled and shows the punch and die complete, with sample of work between the two—a strip of metal with two holes pierced in it. The length of the piece is regulated by the stop on the stripper plate and the cutting edge of the die.

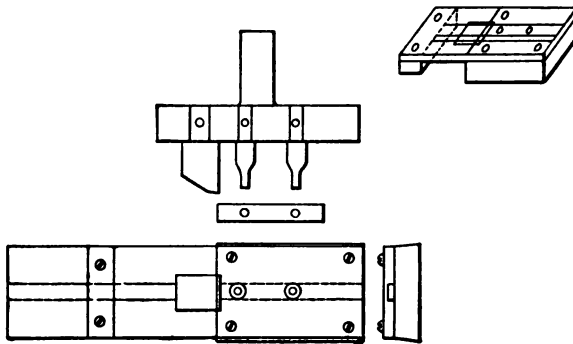


FIG. 166.

Perhaps the greatest difficulty that confronts the beginner is the layout of the die, and for that reason a template should always be made of the piece desired to use for this purpose. In this simple construction of course this is not essential. The metal is fed into the stripper plate either by hand or automatic feed up to the edge of the die; the punch pierces the two holes and trims the edge, and on the upward stroke of press the metal is fed against stop and the same operation cuts off the one already pierced, and pierces the other. In other words a hundred and one strokes of the press will make a hundred punchings of this particular kind.

Very often in simple piercing dies, as the one just

described, a cast-iron block is used, and small tool-steel bushings inserted for the die edges, a steel plug being driven in on the end and squared for the cutting-off edge, thus saving a large piece of expensive tool steel. This is good construction in more advanced die making also, because it allows very economically for replacement of broken edges.

In all simple gang die construction the piercing is first done and the blanking afterward. This statement covers only the construction of gang punches, and does not mean

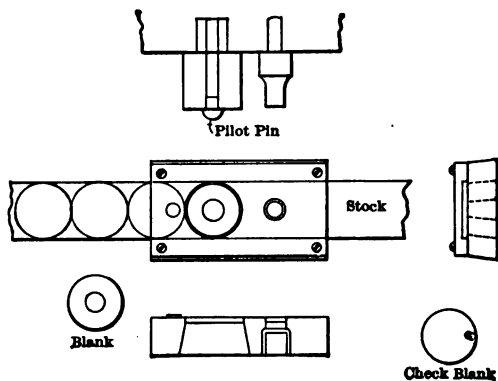


FIG. 167.

that this is always the law in piercing and blanking. When the punching is to be afterward formed, the piercing would be done after the forming, because of the tendency to draw the metal in forming, which might change the position of the holes if they were put in in the first operation.

Stop Pin. Fig. 167 shows a piercing and blanking die for an ordinary washer. The stripper plate has been removed to show the stop pin, against which the metal is fed after each punching; this is designed as a feed regulator without which the operator would be at a loss to know how far to push the metal forward.

Pilot Pin. In addition to this feed regulator, which should allow for the metal to be fed a slight distance in

advance of its true place, the pilot pin is used, and its function is to locate accurately the pierced hole in relation to the blank, the center, in this particular washer blank. The shape of the pilot pin should resemble the beehive construction, so that when the point once enters the hole it will draw the stock in proper position for blanking.

Layout of Die. Using the washer as a template, when the die stock has been prepared for laying out, that is, the surface smoothed and covered with either Prussian blue or coppered by the bluestone solution, a center line should be drawn, and the template laid with the center of the hole on this center line, or the dividers set to the outside diameter and a circle drawn. This locates the blanking die hole, and with the same setting of the dividers another circle should be drawn on this same center line with the edges just touching the edge of the other circle, and this locates the center point for the piercing hole. If the hole is out of center, as in a check blank, the piercing hole should be laid out with the hole on the center line at the far end of the circle away from the blanking hole to prevent possibility of cracking in hardening. It is not always wise, however, to place the blanks so closely that one hole will break into the other, on account of the metal breaking up into small pieces and preventing the proper feeding of the metal. Usually the space allowed between edges and blanks is the thickness of the metal cut. Hence to punch a 1" diameter disc from metal $\frac{1}{8}$ " thick, the stock would be $1\frac{1}{8}$ " wide and $\frac{1}{8}$ " between blanking spaces. This rule is not always observed.

The third construction, as shown in Fig. 168, illustrates the open stripper plate, that is, fastened on one side only, to facilitate the handling of the product being punched. It is a piercing die for armature core and also shows different construction of pilot pin. This is shown on side of punch and is designed to properly space the piercing in the core ring.

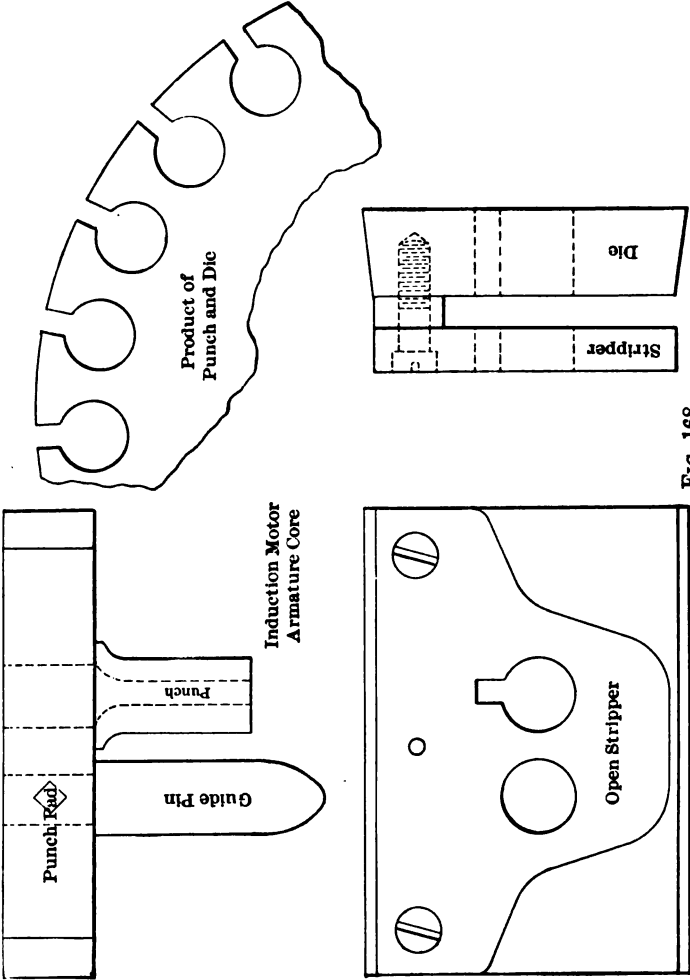


FIG. 168.

This punch is irregular in shape, and that brings us to the next step for consideration in die making—order of construction.

In the case of the first two dies discussed there were no irregular forms to produce, hence the simplest machining operations only were necessary, but now we have to deal with an irregular form, so the die would be made first and the punch last. The reason for this is that the die may change its shape in hardening, and, again, whatever shape it may be, it can be used to shear the punch. Care should be taken, however, to see that very little metal is left in the punch for shearing, also that it should be put under the press for shearing and not in the vise, because parallelism is essential for forcing it down into the die straight.

It is the custom and is logical, that for all irregular forms the die is made first complete and the punch shaped to it.

Sizes of Die Stock. There is no well-defined law laid down for the size of the steel that should be used for certain size blanks. Some use the method of allowing the width of the blank on each side of the hole, as, for illustration, to a blank 1" diameter the stock would be 3" wide.

Stripper Plate Screw Holes. The layout of these is very important, because being close to the end, the edges are liable to crack in hardening. A rule the author has always followed is to allow the diameter of screw between the edges of the die and the sides of the screw holes; for instance, if $\frac{5}{8}$ " screws were used, the centers would be located $\frac{15}{32}$ " from each edge of die, and when hardening die these are plugged to prevent a steam pocket during the cooling process.

Angle of Punch. The next step in the development of die making is to be able to save stock—to get the greatest number of blanks out of a given weight of stock. This seems desirable from an economic standpoint at least, but very often it is not possible to consider this economic point.

Flow of Metal. This is really the determining factor in

the layout of punches and dies, especially for irregular shapes, where the area of metal on one side is much greater than that on the other side, because it is desirable to feed the metal from the rolls in which it is sold, and this irregular area, if not thoroughly considered in the layout, would create a constant bend in the stock, due to greater flow of metal on one side, with the result that very soon we would cease to get a perfect blank, and would have to cut the metal into short strips.

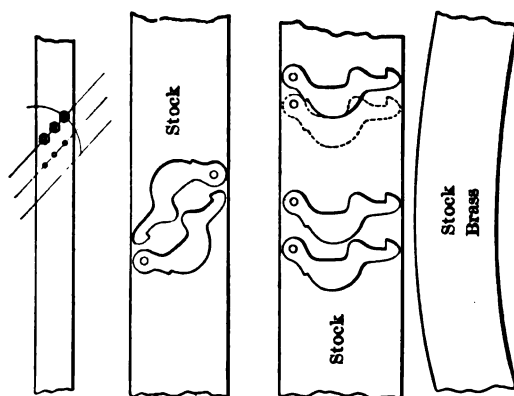


FIG. 169.—Flow of Metal.

Fig. 169 illustrates very clearly the conditions just described, also angular position of punches in relation to the plane of the stock. It also clearly shows the saving in waste metal both in width of stock and between punchings. Another way to overcome this flow of metal is to skip a punching space, and after the whole strip has been punched, turn it end for end and blank out the intervening spaces.

This same cut illustrates a layout for small hexagonal nuts to further endorse the angular layout, but there is another very important consideration to be met, and that is the forming of the blanks afterward. If they are to be

formed into other shapes we must consider the grain of the metal, so that it will not break in forming, and this restricts to a great extent, or rather indicates to us, the limit of angularity of punch. Another point in tool making: Lay out punch and die with regard to the use the blank will be put to; if it is to be formed, *consider the grain of the metal.*

Alignment of Punches and Dies. The method of obtaining this important feature is to work the die stock and its punch pad together. This is a very simple matter if the blank is round, but in irregular forms not quite so easy. The old method of taking a steel set and driving over the punches by creating a flow of metal in the punch pad gave alignment on the extreme edges only, but if an attempt was made to push the punches down into the die it was found that they were bent. The correct method eliminates this haphazard way.

After the die has been finished the punch pad should be clamped on its face and the holes transferred, using the die as a template. As to bending the small piercing punches, this will happen if the blanking and piercing punches are left the same height. The blanking punch should perform its function before the piercing punches start theirs; hence *the face of the piercing punches should be below that of the blanking.*

Clearance in Dies. This varies according to the nature of the material punched, but common practice gives about $\frac{1}{4}$ " on a side. The only reason that any clearance is necessary is to clear the die of the punchings, as they are slightly larger after being punched, due to the compression during the blow and the release from that compression after leaving the strip.

It is very readily observed that there should be as little clearance as possible for the long life of the die in repeated grindings. This is more important if the metal punched is very thin, because the thinner the material is that is to

be punched the closer the punch must fit the die. Remember that the punch has nothing whatever to do with the outline or form of the blank, but is simply used to keep the blank from bending or curling on the edges. For example, see what effect a lead pencil will have on a piece of paper that is held on a die 1" diameter hole. To punch metal of considerable thickness the punch does not have to fit the die accurately; it may be $\frac{1}{8}$ " loose all around and give a perfect blank, because the resistance of the metal itself to bending, due to thickness, is sufficient.

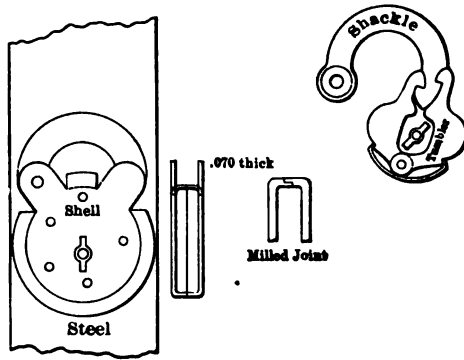


FIG. 170.

Fig. 170 well illustrates more clearly the question of piercing after forming. In the case of the lock shell here shown, it is clear that both sides are controlled by the milled joint on the edges. It is therefore essential that the rivet holes should be in perfect alignment to prevent any possible draw on either side of the shell.

Spring Stripper Plates. The use of these is primarily determined by the product that is to be made—whether the piece punched out is to be used or the stock that is left, as would be the case in sheet metal strainers, electrical instruments, small brass trimmings for lamps, etc., where the punching becomes perforating and very small piercing

punches are to be used, in which case the spring stripper is carried with the punch, and is made to act in very many cases as guides to keep the small punches from breaking.

The construction of these spring stripper plates is very simple, being held on the punch pad by means of a number of screws and around each screw a coil spring to act as buffers for the stripper plate, as shown in Fig. 171. The

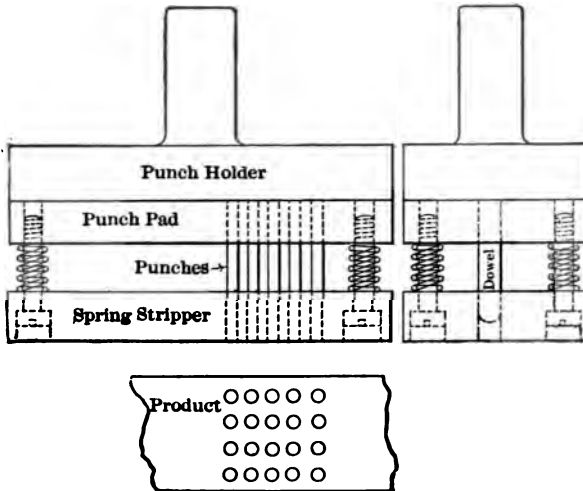


FIG. 171.

screws should not be used for guides, but dowel pins should be used in all cases to keep the stripper plate in perfect alignment.

Stripper Plate Summary. First. Closed stripper is to be considered when many thousands of blanks are required and where width of material varies. The metal wears the sides of the stripper plates, hence it is economy to build it up rather than to make it in one piece and shape opening.

A thin piece of metal laid on two narrow pieces forms the same combination, and in addition allows for hardening the side plates to take care of the wear. Sometimes a

flat spring is used on a side plate to keep the stock always against one side. Sometimes small hardened screws are used for adjustment for variation in width of stock.

Second. The open stripper facilitates the handling of blanks that are to be pierced on edges, such as armature core discs, etc.

Third. The spring stripper is adaptable for perforating work where the piercing punches are exceedingly small and a guide is essential. Without guiding the punches, good practice has considered the minimum size of punch as that of the thickness of metal to be punched. For example, a punch $\frac{1}{16}$ " diameter to cut stock $\frac{1}{16}$ " thick.

Shearing. When large areas are to be punched which would involve tremendous power due to the resistance, the die is sheared, and the action is that of a pair of scissors. A little study of the question of shear will readily determine how to shape the top of the die to get this effect. The question of bending the blank or stock determines whether the shear is on the punch or die.

Sectional Dies. By sectional dies is meant the built-up die. It is only within the last few years that sectional dies for general all-around die construction has become the practice. It was only the very large dies that this feature of construction applied to, but it is now recognized that it is economically adapted to small dies as well.

An irregular form that presents many sharp angular edges is particularly adapted to building up, where each extended point can be replaced without much expense. It is a question in the mind of the author whether the economic entered into the question of sectional die construction, even in the very large dies, as much as the question of facilities for hardening.

Again, the determining factor is the use for which it is intended, whether many thousand pieces or a few hundred are to be punched, and finally the question of maintaining accuracy.

A large die lends itself to this construction, because of the ease with which the parts can be handled; after hardening if a piece warps it can be forced into shape, and is easy to get at for grinding, etc. The accuracy of alignment is obtained by dowel pins.

Economizing on Grinding Surface. Fig. 172 illustrates clearly another economic feature of die construction which enables the die to be reground in least possible time because the surfaces have been reduced.

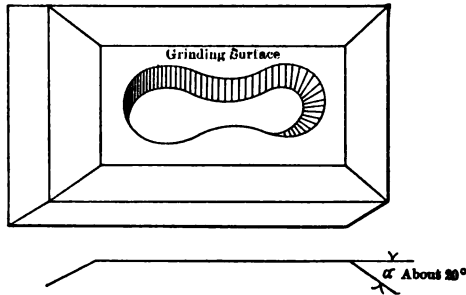


FIG. 172.—Cutting Down the Grinding Face for Economy of Time.

Forming Tool. To carry one step farther the principles involved in the preceding discussion, Fig. 173 illustrates the forming operation of a shell, after it has been blanked, showing method of applying spring knockout, which performs the same function as a stripper plate, namely, that of releasing the work. The bottom former is shaped to size of blank as indicated by recess on top of bottom former. The blank fits into this recess and the plunger which is here shown, with spring depressed, is in its normal position at the top of the former, within the thickness of metal to be formed. This plunger is capable of adjustment by means of nut on bottom of rod. There is no tendency for the shell to hug tight on the top former, because the tendency of all metal to go back to its original form after bending will

prevent this. On the upward stroke of the press, the plunger which is actuated by the coil spring pushes the formed shell to the top and it is brushed off and a new blank inserted.

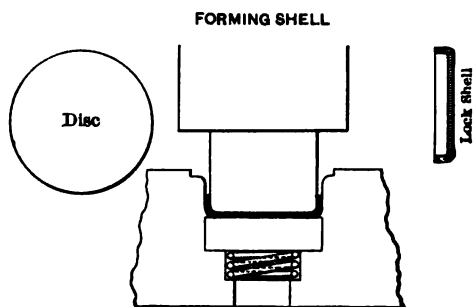


FIG. 173.

Angle Forming. It is not difficult to form a piece at right angles; any type of forming tool will give this result, and if this were the only requisite, the problem would be easily solved; but invariably the bend must bear a different

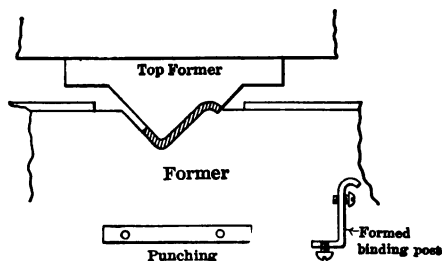


FIG. 174.

relation to some hole or holes, or length, and this complicates the problem considerably, because the metal must flow or strain at the place it is bent, and this means that the greatest force is applied here. The parts that are free will move along the line of least resistance.

Fig. 174 illustrates a forming tool for bending posts for

electric light sockets. The product, to be of any value and usable, must be so formed that the wire binding screw must always come at the same place under the top bend to insure the holding of the wire, and the screw which holds it in its porcelain base must always be in the same relation to the bend.

The principle involved in this type of construction is that the force required to bend it is equally distributed, on the theory that both sides of the former, having an angle of 45° each, balance the forces which tend to pull the metal either way. The construction of the tools needs no detailed description. The question of material again is determined by the number of pieces needed.

Reproduction Tools. The first reproduction tools of which we have any authentic record date back to the Early Egyptians in their reproduction of pottery shapes, where they used the original vase or piece of pottery as a mold to reproduce others of same design.

In the art of printing and lithographing the next actual reproduction step was taken, in the making of single letters, afterward in sentences and later in whole page reproductions of type, and this enabled a greater production and necessarily at lower cost to the consumer. Books are now put up in 10,000 editions, and it would take an expert to detect the slightest difference in any of the product. The modern uses are more largely confined to machine construction and things mechanical, and a few fundamental principles will show the wide application of jigs and fixtures.

CHAPTER XIX

TOOL MAKING—*Continued*

JIGS AND FIXTURES

Their application to modern production. Fundamental principles involved in their construction. Different types. Simplest forms and their development. Three-point contact. The cam as an effective locking device.

THE distinctive difference in the classification in tool making, between punch and die work and jig and fixture work, is in the nature of the product rather than in the tools themselves. Both have the same end to meet—the making of a great number of parts all alike. Punch and die work really is reproduction work, but not in the same sense as that of jig and fixture product. This applies to very large work as well as small, and irregular in shape, as coming from the foundry, forge or machine shops, and finished forms lend themselves to it as well. They are not confined to one class of work, but find a need in every branch of the mechanic arts.

There are drill jigs, milling jigs, planing and shaping jigs, boring jigs, assembling jigs, etc., all used for the purpose of interchangeability of product.

The day of single machine construction or piece of apparatus has passed, and in every branch of manufacture the keynote is economy, and this can only be effected by building in large quantities, and by means of jigs and fixtures these large quantities can be made interchangeable. In the early days locks were made by skill, or hand if

you please, but when there was a demand for hundreds and thousands—it is millions now—so with the sewing machine, lathes, planers, shapers, milling machines, and all classes of machine tools, automobile engines and accessories, locomotive parts, etc., due to jigs and fixtures, punch and die and forming tools, are now more accurately made and sell at less cost.

Template. The simplest form of reproduction tool is perhaps the template, Fig. 175, made in any form desired to reproduce shape rather than quantity, yet the interchangeable idea is nevertheless paramount, and this is

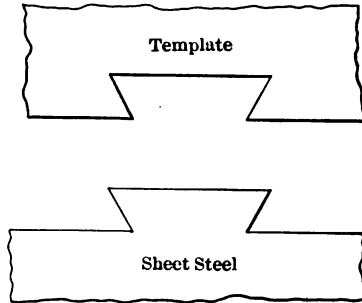


FIG. 175.

the only fundamental principle involved in it. From these templates tools are made to irregular shapes by skilled workmen, and these in turn reproduce the finished product from the hands of unskilled workmen, hence, jigs and fixtures themselves call for the highest art of the skilled mechanic, and their use eliminates this demand, which rightly classifies them as cheap-production tools.

Principles Involved in Their Design. They must be nearly fool-proof, that is they must be so constructed that the cheapest labor can operate with them. They must be so designed and constructed that the product can be held always in the same relation, and at the same time put in and taken out in the shortest possible time. This means

that the method of locking up must be simple and accurate, and the cam method adapts itself readily to this function. The smallest area of contact that will still leave it rigid is called for, which is effected by standard or lugo, which leaves room for chips and cuttings underneath.

Three-point Contact. Much has been said and written on the method of holding work in the jig, and the three-point contact has come to be considered as the only real thing. The fact is that the shape and nature of the work determine this point largely. It is desirable and necessary to have the work held so that it will not rock, and the three-point contact will accomplish this result wherever it can be used—much as a three-legged stool will rest securely on a round surface, regardless of any variation in the length of its legs—a feat unattainable with four legs. But it must be remembered that all kinds of irregular shapes are jigged, and in many cases more bearing points are necessary and can give equal rigidity.

The materials of construction are such that they will not change their shape due to strains either by clamping or when the tool performs its function. Cast iron lends itself to this feature as the main body of the jig, or fixture, as it can be poured into any irregular shape and at the same time the economic factor of cheapness is desirable. Cast iron in itself is too soft to use when much wear is to be considered, and in this case tool-steel bushings, which have been hardened, ground and lapped, are inserted in the cast iron, and these can be removed at least cost in case of wear and breakage.

Simple Drill Jig. Starting with the simpler types of these tools, Fig. 176 illustrates a drill jig for drilling the ends of switchboard terminals for the wire. An ordinary round bar of steel is caught in the chuck and finished in a single clamping. Care must be taken to insure the small hole alignment with the larger bore which fits the outside of the brass. This is a free sliding fit, and after boring

or machine reaming to size the small hole should be started with a boring tool and bored at the start to the size of the drill or cannon bit, which will then carry through

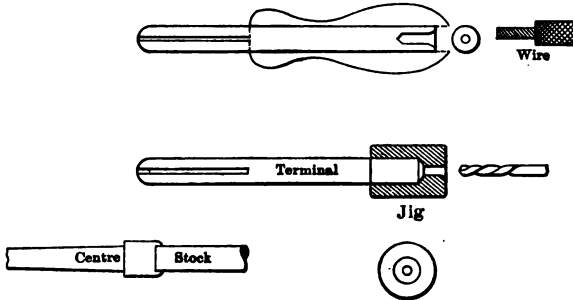


FIG. 176.

true. The use of this tool will avoid laying out each piece and give accurate center drilling.

The depth of hole can be gauged by slipping over the drill a sleeve of definite length that will act as a feed stop.

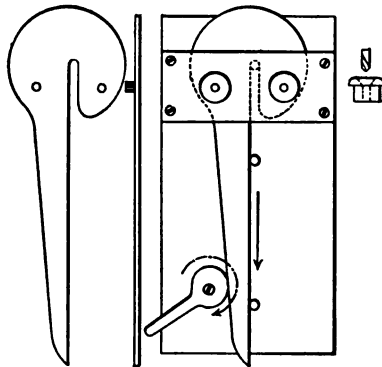


FIG. 177.

The illustration shows a type of center that can be used to good advantage, but the cup center that is found on all sensitive drills will perform the same function.

Method of Applying Cam Action. Fig. 177 illustrates another type of drill jig for drilling a center square, a

tool that will be familiar to all the old-time mechanics, and is taken simply to show certain fundamentals of design which will enable the operator to arrive with the desirable feature—accuracy.

The Center Square. This tool is designed primarily to find the centers of round stock readily, although it can be, if properly made, used as a square. The two small pins which project from the face of the tool must be equidistant from the straight center edge, and at the same time be square or at right angles to it. Care must be exercised to insure same diameter for the pins.

The Jig—Second Type. This is made of cast iron with flat steel plate screwed to it, leaving just enough between to stop the stock under small tool; steel buttons are inserted in the plate and on the base stop pins are located at right angles to the holes to be drilled. The cam is so arranged that it draws the product down to its stop on top and at the same time it fastens it against the side pins.

The design is capable of extension if many hundreds of the tool are needed. Legs, for instance, would be desirable on account of chip and dent on the table of drill.

Third Type of Drill Jig. Fig. 178 illustrates still another simple drill jig for use in drilling microscope bases, where the leg or standard principle and locating pins are shown, but more particularly the method of securing same size to condenser hole. This is rounding, and the hole in the jig is made to size and acts as stop for tool that gives the particular shapes.

Turning Fixture. Fig. 179 illustrates a type of mandrel or special fixture for turning the open side sleeve of microscope. It is essential that the square recess be in the center of the two sides, which are really the locating spots on the slide, and when placed in position should leave an equilateral triangle for the sliding bar. The mandrel is made on centers, the sides and top milled to shape as shown in illustration, leaving enough for grinding after hardening.

The collar in front of nut is made to fit accurately with the outside diameter the size of the finished product, so

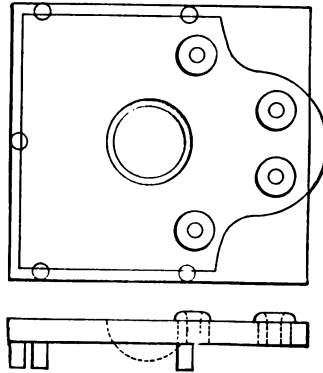


FIG. 178.

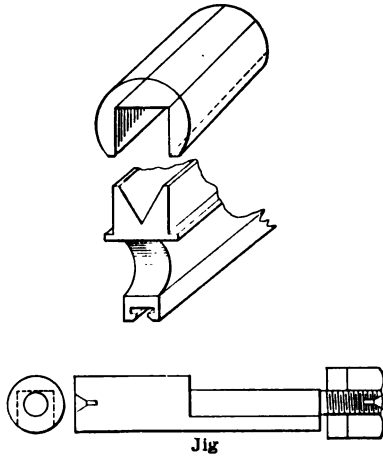


FIG. 179.

that time spent in calibration is eliminated. The work is held in by the nut, and very accurate and satisfactory results are possible with very little skill.

Tube Fixture. It is often necessary to machine very thin tubing, and the question of holding it without injuring it is serious. Fig. 180 illustrates a method of construction that is applicable to a wide range of work. It is designed to hold the tubing for tapping, which requires more rigid holding than would be called for if doing any other type of machining; no explanation is really necessary, as it speaks for itself.

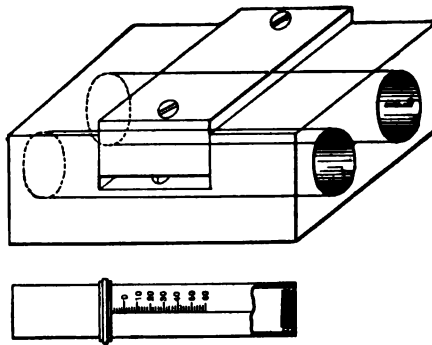


FIG. 180.

The foregoing simple illustrations are given to demonstrate a few of the fundamental principles of design and why so designed, and no matter how complicated the jig or fixture may be, they are really the determining factors in the design.

QUESTIONS ON TOOL MAKING

What is an arbor?

What is a mandrel?

What value has a multiple-tooth cutter over a single cutter?

What are some of the precautions to be taken regarding the arbor?

What is the disadvantage of grinding cutter by hand?

Calculate the number of teeth in a milling cutter 5" diameter.

What clearance has a tooth?

What is a proper amount of land to be left on a tooth?

Why are milling cutters recessed?

What is the advantage in many ways of the recess?

Calculate size and all dimensions for rack teeth for $1\frac{1}{2}$ " pitch.

Make sketch to scale of rack teeth and in ink.

Assume that a template is desired for gear tooth, 3 diametral pitch and 15 teeth.

What is meant by diametral pitch?

What is meant by circular pitch?

Calculate size of wheel.

Draw to some convenient scale, showing pitch, diameter, whole diameter, thickness of tooth, depth of tooth, and how you determine clearance.

Give method of setting cutters and slotting saws on center.

In cutting this same wheel, or template outline, what index circle and how many holes would be used?

What do you understand by simple indexing?

What is meant by compound indexing?

Calculate compound indexing for 69 teeth.

What is a *fly* cutter, and how used?

What do you mean by the term "formed cutter"?

Is there a limit in size to solid cutters? What is it, and what kind of cutters are used above that limit?

Draw milling cutter and work, showing shape of tooth on tap or reamer.

What is a fair speed for milling cutters on tool steel, soft steel, cast iron, and brass or bronze?

What is the proper hardness for milling cutters?

Why is a spiral tooth mill better than a straight tooth?

What advantage is there in nicking the teeth of roughing reamer and milling cutter?

What is an abrasive? Give grades and names of 3 or 4 different abrasives used in machine-shop practice.

How is it graded for fineness?

Give common method of determining the hardness of an abrasive wheel.

What limits the speed of wheels?

What is a safe peripheral speed for an abrasive wheel, such as emery or carborundum?

Between what grades is the great majority of machine shop practice confined?

How does the coarseness and softness affect the wheel as to speed? Should it run faster or slower?

What is the proper amount of taper for a mandrel?

What is the disadvantage of too much taper?

About what amount is generally considered for a driving fit?

For perfect running fit what allowance should be made between the box and the spindle?

Should like metals be run together? Give reasons for or against.

What is the disadvantage of soft-coal fire for tool-steel heating?

What is the disadvantage of forced draft?

What is understood by the term "lapping"?

Give several methods of lapping external and internal work.

What is accomplished by this final lap or finish?

What do you understand by press work?

Why are some presses made inclinable?

What is function of balance wheel?

What is function of clutch?

What is the function of a bolster?

Sketch bolster.

About what angle is given to edge of dies?

What is the value of this angle, and why is there any angle?

Describe a stripper plate, and what it is used for.

How would you dip a die in hardening, and how would you draw the temper?

Why is the die usually made first? Describe in detail.

Why is it better not to have the squares and taps on reamers with sharp edges? Name two reasons.

How do you determine mathematically the size of the squares?

What metal is mostly used where punch and die work is employed? How is it designated?

How do you determine the size of a blank for forming any desired shell?

What is the value of annealing brass? How do you anneal brass and copper?

What is a blanking die? What is a piercing die? What is a gang die?

How do you get clearance in the holes in piercing dies?

What is the disadvantage of too much clearance?

How do you insure the punches and holes in die aligning properly?

How do you lay this out?

What is the advantage of a punch pad for holding punches?

Which is usually made first, punch or die? Why?

In hardening a die how would you dip it?

What are some of the considerations in laying out work on die relative to the material to be used?

(a) What precautions must be taken as to flow of metal and how do you lay out dip to take care of this?

What value has dowel pins and what is their real function?

What is the real function of a pilot pin?

How is a die usually dipped in hardening? Name different ways, giving an idea of the result desired; and why?

Lay out die for blanking and piercing a small scale pan as per sketch. Go into details as to methods step by step and give reasons for each step.

What method is frequently used when dies of very large proportions are to be made?

What are some of the advantages of split dies? Name several.

How is the great cutting resistance overcome?

In stripping metal that has tendency to cling to punch, how would you construct punch?

Describe methods of making die to punch blank as per sketch, showing layout and step by step procedure.

Describe various methods of tempering such a die.

(a) How would you overcome warping in such a die?

Are all punches and dies hardened?

Is it necessary to have punches fit dies in all cases? Give reasons.

Describe the functions of a punch press.

(a) What is a bolster?

(b) A punch pad; its function?

What is the function of stripper plate?

(a) Of what material is it usually made?

How are the different metals designated?

How is die held in place?

(b) What angle is usually adopted for sides?

In setting die, why is it essential to have it well bedded?

Give methods from start to finish for laying out die to punch the following piece.

Example: Lay out die to punch check 1" diameter, hole $\frac{1}{8}$ " diameter, center of which is $\frac{1}{8}$ " from edge. Give in detail.

Is laminated metal efficient for dies? Reasons for and against.

What is stop pin for in a die?

What are the methods employed for centralizing punching?

In gang punching are all the punches the same height? Reasons?

What piece is made first, the punch or die? Why?

What methods are employed to assure alignment of punches with die?

Give several methods of hardening dies.

(b) Give several methods of hardening punches.

(c) How avoid change of slope in hardening?

(d) Different baths for cooling?

(e) Tempering the latter?

How would you harden drawing die?

How is irregular shaped punch sized to fit die?

How is the irregular flow of metal taken care of?

What is the economical way to let out die to save metal?

What is a drill pin?

(a) What is its function?

Describe the simplest form of punch and die.

How much wearing life is allowed for the cutting edge of die?

In large punchings how do they overcome the resistance of the large area?

How far should screw holes for stripper plate be from edge of die?

How would you avoid the full frictional resistance to the tap, in tapping them?

What is a good method of hardening to prevent change of shape?

Describe a jig, and its functions.

What are jigs for?

What metals are used in construction usually?

Why is the three-point contact desirable?

If made of machinery steel, for drilling, how would you treat to prevent wear?

What mechanical principle is used for fastening work in jig?

What provision must be made for adjustment for irregular castings?

Is the economical reason the chief reason for the use of jigs?

(b) Name other reasons.

Design simple jig for drilling $\frac{1}{4}$ " hole in end of round stock $\frac{1}{2}$ " diameter.

(b) Give size of outside diameter and length.

(c) What material would you use, assuming there were only 200 to drill?

CHAPTER XX

SYSTEM

Method of keeping track of work through the various departments. Time, stock and repair cards. Construction chart. Construction sheet and its uses. Job order cards and how used. Their value from an economic standpoint.

THE mechanic is only half educated in his trade unless he has a full knowledge of the details of his work.

It is not enough to know only how to do the particular piece of work, but the man who studies, along with his regular work, the functions of the executives who are running the plant, how they take care of the plant from raw material to finished product, is more likely to become one of the executives.

There are many complicated systems of keeping track of time, stock, material undergoing construction, etc., which do not lend themselves to the smaller shops or organizations. The following system has been devised and tried out by the author with very satisfactory results.

In any numbering system it is important that proper emphasis be laid upon the fixing of that number.

The problem presents three distinct phases for solution:

1. The main number must never duplicate.
2. The method of assigning this number must be simple.
3. Certain figures in the number should have the same meaning in all departments, and unlimited expansion should be possible to cover details without altering the main number.

SEC. <u>A</u>		DEPARTMENT		JOB NUMBER	
TIME CARD				<u>542-1</u>	
JOB <u>Tapping Machine</u>					
CHECK # <u>340</u>		FOREMAN <u>[Signature]</u>			
PART <u>19000</u>		NO. OF PIECES <u>1</u>			
MATERIAL	OPERATION	TIME IN HOURS			
<u>C.I. Blowing</u>	<u>6 1/2</u>				
REMARKS					TOTAL TIME <u>6 1/2</u>
DATE <u>Jan 7, 1911</u>		INSTRUCTOR OR GEN'L FOREMAN <u>[Signature]</u>			

8108 5000 12-1-10			A		
CHECK NO. <u>388</u>			STOCK ORDER CARD		
PRESENT TO STOCK CLERK OR TOOL-ROOM ATTENDANT					
PIECES	JOB NO.	MATERIAL			
<u>3</u>	<u>342.4</u>	<u>Concible Machine steel</u>			
		<u>7/8 x 1" Dia</u>			
DATE <u>Jan 7, 1911</u>		INSTRUCTOR OR FOREMAN <u>[Signature]</u>			

JOB NO. <u>599</u>		DEPARTMENT	
REPAIR ORDER CARD			
RETURN TO HEAD OF DEPARTMENT WHEN WORK IS COMPLETED			
MACHINE OR APPARATUS		DESCRIPTION OF REPAIRS	
<u>Counter shaft on Lathe # 11</u>		<u>Bush pulley & adjust clutch</u>	
		TIME <u>7 1/4 Hrs</u>	
DATE <u>Jan 19, 1911</u>		(SIGNED) <u>E.A.W.</u>	

FIG. 181.

000	100	200	300	400	500	600	700	800	900
CHEMISTRY	PHYSICS	STRENGTH OF MATERIALS	ELECTRICAL LABORATORY	STEAM LABORATORY	MACHINE SHOP	FOUNDRY	WOOD WORKING	FORGE SHOP	MISCELLANEOUS
542	Tapping Machine	227	Test pieces						
1	Base	1	Liquor						
2	Head	2	Compression						
3	Rivets								
4	Shafts	243	Cement Moulds						
5	Tools for same								
547	Mandrel Press								
1	Base	3526	Dig for Masses.						
2	Spindle		mineral						
3	Gears	790	Remodelling Pattern						
			maven lathes.						
1440	Flexible Couplings								
1441	Testing Tables	793	Wood lathe Centres						

DEPARTMENT CLASS NUMBER		FIGURES PLACED AT THE RIGHT OF THE DECIMAL POINT INDICATE DETAIL		MISCELLANEOUS CLASS NUMBER	
00.		.0		9-00	MODELS
10.	TRANSMISSION EQUIPMENT	.1		9-10	
20.		.2		9-20	
30.		.3		9-30	
40.	NEW EQUIPMENT	.4		9-40	
50.		.5		9-50	BUILDINGS AND GROUNDS
60.		.6		9-60	
70.		.7		9-70	
80.		.8		9-80	ENGINEER'S DEPT.
90.	REPAIRS	.9		9-90	

FIG. 182.

542		DEPARTMENT		Machine SHOP	
JOB NUMBER		CONSTRUCTION TICKET			
JOB <i>Tapping Machine</i>					
DATE DELIVERED <i>Jan 6</i>		COMPLETED <i>Jan 11</i>		WANTED <i>Jan 13</i>	
NO. OF PIECES WANTED <i>1</i>		INSPECTED BY <i>CDK</i>			
PART OR OPERATION WANTED <i>Complete Machine</i>					
HOURS LABOR @ 22.30		6 60			
EXPENSE		2 75			
COST OF STOCK		4 87			
TOTAL		\$ 14 22			

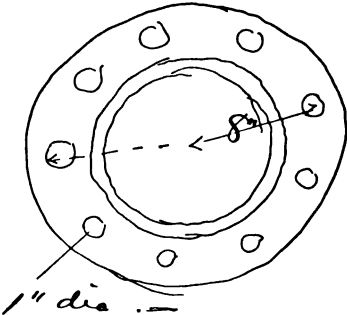
542		DEPARTMENT		Dept. A	
JOB NUMBER		COST CARD			
JOB <i>Tapping Machine</i>		ORDERED BY			
STARTED <i>Jan 7</i>		COMPLETED <i>Jan 11</i>		WANTED	
	CARDS	EXPENSE	LABOR	STOCK	TOTALS
DRAWING ROOM		2 75	6 60	4 87	14 22
PATTERN SHOP					
FOUNDRY					
FORGE					
MACHINE					
OUTSIDE or I.F.E.				6 32	
DESIGNED BY <i>CDK</i>		TOTAL COST		\$ 20 54	

542		DEPARTMENT		Dept. A	
JOB NUMBER		DRAWING ROOM CARD			
JOB <i>Tapping Machine</i>		ORDERED BY			
DATE STARTED <i>Jan 3</i>		COMPLETED <i>Jan 6</i>		HOURS <i>2.7</i>	
	PATTERN SHOP	FOUNDRY	FORGE SHOP	MACHINE SHOP	
NUMBER OF SETS WANTED				1 ✓	
DATE DRAWINGS DELIVERED				<i>Jan 6</i>	
DATE WORK COMPLETED				<i>Jan 11</i>	

FIG. 183.

JOB NUMBER	<u>X 983</u>	DEPARTMENT	<u>July 7</u>
EMERGENCY SKETCH		DATE	
JOB	<u>Pipe flanges</u>		
ORDERED BY	<u>Department E.</u>		

*Draw 3 flanges
as per sketch.*



1" dia.

APPROVED BY *W.H.*

FIG. 184.

DEPARTMENT			CONSTRUCTION SHEET		JOB NUMBER			
Machine SHOP					542			
JOB Tapping Machine								
ORDERED BY Department A								
NO. OF PARTS	PARTS	WORKMAN OR CHECK#	DATE	TIME	MATERIAL	BEGUN	FINISH	TOTAL TIME
1	Base	#312						
1	Head Stock	#345						
1	Tail Stock	#387						
3	Rivets	#302						
		#323						
		#349						
3	Shafts	#388						
		#303						
		#311						
	Tools for same machine							
	Drill bit	#321						
	Drilling "	#329						
	Mounting	#394						

APPROVED BY _____

FIG. 185.

The reason for the first of these propositions seems self-evident.

Second. Any instructor, after he has given a title to the work he wants done or the machine he wants made, must be able, by simply a glance at his numbering chart, to write down the main number for the job.

Third. Subdivisions are necessary because in the shops we wish to keep track of the time, etc., on certain parts of the job as assigned to one or a group of students; while uniformity in numbering subdivisions and the possibility of expansion is necessary in the drawing room and for foundry patterns, because every single detail of the job may require a distinctive number.

Our solution of these problems is set forth in the following pages.

Type of Job Number. The main number shall consist of two figures and a consecutive figure or figures followed by a decimal point, as 528., 7985.

Type of Emergency Job Number. All emergency jobs shall have the prefix X placed before the main number, as X529., X7986.

This number shall stand for one job as a whole, no matter whether the work takes two hours or five years to complete. This number shall not be duplicated, and the time and cost of every detail of the job will, when finished, be charged to this main number.

It is this job number alone that departments, other than construction departments, will use to trace their work.

Type of Detail Number. In drawing room and shops a figure will often appear to the right of the decimal point of the job number, and sometimes a figure and a letter, as 528.4, 528.45C.

Determining the Job Number. The first and second figures of the job number shall be fixed for each department.

The first figure indicates the department; the second figure shall indicate a definite class of work for that department, except in the Miscellaneous or 900 class. This second figure shall indicate in the five cases given below, the same general class of work in all departments.

<i>Department Number.</i>	<i>Class Number.</i>
000 Chemistry	00
100 Physics	10 Transmission equipment
200 Strength of materials....	20 Exercises
300 Electrical laboratory....	30 Exercises
400 Steam laboratory	40 New equipment
500 Machine shop	50
600 Foundry	60
700 Pattern shop	70
800 Forge shop	80
900 Miscellaneous	90 Repairs

The five class numbers unassigned by the Construction Committee may be assigned as occasion arises by the heads of the various departments, but when once assigned shall not be changed.

A suggestion as to what is covered by the class headings is as follows:

Class Subdivisions. 10. *Transmission Equipment.* 1. All hangers, brackets, shafting, couplings, pulleys, clutches, gearing, etc., which aid in transmitting the motive power from engine or dynamo to machines.

20, 30. *Exercises.* Such work in any department that is used simply for the elementary instruction of the students, not as construction or project work.

40. *New Equipment.* Important instruments or machines which will last ten years or more.

This is possible of further subdivision by using one of the free numbers.

90. *Repairs.* Any repair or break-down job to existing equipment other than transmission equipment.

Determining Detail Numbers for Jobs. Additional figures may be placed at the right of the decimal point to be used in subdividing the work on any job. The first figure should be given as nearly as possible in accordance with the following general classification, as:

- .0 Used to designate the assembly drawing.
- .1 Wrenches, vises, small equipment.
- .2 Plates, washers, etc.
- .3 Stationary constructive part.
- .4 Movable constructive part.
- .5 Stationary motive part.
- .6 Movable motive part.
- .7 Pulleys, gears, etc.
- .8 Fluid transmission.
- .9 Miscellaneous.

Further numbers may be added beyond this figure in sequence at the option of the department concerned.

Detail Letters. To designate any detail of this main subdivision, the letters *A, B, C*, etc., may be used, referring to the drawing of the detail of said part on the detail sheet. The assignment of these letters is left to the discretion of the Instructor of Drawing.

It is suggested that the use of this letter be largely confined to the drawing room, and to the numbering of individual patterns. That in other shops the number covering the main subdivision of job be given, and the name of the particular detail piece be written out.

To Determine the Numbers in the Miscellaneous or 900 Class. The figure next to the 9 shall indicate the department which is to do the work, as designated by our base numbers. The subsequent figure or figures preceding the decimal point may be assigned consecutively; or the third figure be a class figure, in accordance with the classification given below, with the consecutive numbering fol-

lowing this. The choice of these two methods is optional with the department concerned in doing the work.

Classification for 900 Class.

- 9-00 Models.
- 9-10 Jobs belonging to students.
- 9-20 Jobs of persons not connected with the Institute.
- 9-30
- 9-40
- 9-50 Buildings and grounds.
- 9-60 S. & T. department general—plumbing—Fresco.
- 9-70 Art department or Gymnasium.
- 9-80 Engineer's department.
- 9-90

NOTE: Substitute for dash base number of department which does the work.

Detail numbers may be placed at the right of the decimal in accordance with the regular system.

How to Proceed in Assigning Job Numbers. The head of any department shall be responsible for assigning the number to the jobs of his own department. He should determine the title and number of the job and set these down first on a job number chart furnished by the Construction Committee and kept in a conspicuous place in his office. After the number and title have been duly entered on said chart, they should be placed on sketches for the drawing room or on emergency tickets and sketches for the shops.

The object of this is to avoid mistakes in the consecutive numbering.

In carrying out this system the economic side is to be always clearly kept in mind.

When any work in the way of equipment, construction or repairs is to be done with student labor, two general classes of jobs will naturally present themselves.

Regular jobs, which require considerable preparation in designing and drawing.

Emergency jobs, which can be made thoroughly clear by simple sketches.

The former shall have the necessary tracings and blue prints made.

The latter shall have sketches with sufficient data for the efficient execution of the work.

The instructor wishing drawings, tracings, or blue prints made shall present to the head of the drawing department the necessary sketches and data.

Construction Tickets for Regular Jobs. When drawings are completed, construction tickets, printed on salmon cards, shall be made out in duplicate for each part to be constructed and for each shop that will have work to do on said part; also one cost card, as directed under subsequent heading. One set of the construction tickets shall be kept on file in the drawing office; the other tickets shall be distributed as needed with all the necessary blue prints and bills of material to the various shops. On the completion of the work the tickets shall be returned to the drawing room office, so that the duplicates may be filled out, when the shop tickets will be sent back to the department which performed the work.

Construction Tickets for Emergency Jobs. Interdepartment orders for construction or repair work, which cannot be done while you wait, i.e., completed within one day, requiring not more than two class periods, nor employing more than two men, shall be filled out in duplicate by instructor wishing the work done. He shall use the construction ticket form on buff card; send one card to drawing office for filing, and one to the shop which is to do the work, together with the necessary sketches or directions. On completion of work the shop ticket shall be sent to drawing office, as in the case of regular construction tickets.

The construction ticket shall show the following:

Name of job; its number; shop in which the work is to be done.

Dates: When wanted.

Dates: When drawing or pattern is delivered.

When work is completed.

Part or operation wanted.

Number of piece wanted.

Hours of labor.

Expense (sundries bought for this particular job).

Cost of stock.

Signature of instructor (which is virtually a receipt for the completed work).

These tickets shall be printed on salmon-color cards for regular jobs and on buff cards for emergency jobs.

Cost Cards. When the construction tickets are being made out for any regular job one cost card shall be headed with number and name of job; date of starting, and the name of person ordering same, and person who designed the work.

This shall be printed on blue card and shall be kept on file in front of construction tickets to which it refers, and will serve as an index card for same.

When the construction tickets are all in on any particular job the record of the cost card shall be completed. The service of this card is to sum up the total cost in hours of labor, expense and material for the whole job.

Once a year the emergency construction tickets shall be tabulated, and where there are more than three of the same class, a cost card shall be made out, summing up the data contained therein.

Construction Sheets. When the shop instructor receives a construction ticket for any job, he shall make out a construction sheet giving the number and name of job, and assigning the parts and operations to his students.

This sheet is designed as a record sheet for the instructor, for the job in detail in his own judgment.

The exact method of using this sheet will of necessity vary in the different shops.

Time Card. At the end of each class period every student shall fill out a time card and deposit it in a box especially provided for it.

On this ticket the student shows the number of the job on which he has been working, the part, the number of hours spent on it, and the material used for it.

From these cards the instructor fills out the data on the construction sheet.

When the job is finished, the instructor O. K.'s the construction sheet, and summing up the data, transfers record of same to construction ticket.

The construction ticket is then sent with completed job to person ordering it, who in accepting the work signs said ticket and returns it, as a receipt for work done, to the shop instructor.

The illustrations will clearly show the method of using the system, as they show a job being carried through the regular order, The Tapping Machine 542—Figs. 181, 182, 183, 184, 185. This is only intended as a simple system, and to show the simplest way of following up the various jobs that are going through the different shops. It is capable of expansion or modification to meet almost any need.

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